CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT — DANEMARK

JOURNAL DU CONSEIL

VOL. XXIV · NO. 2

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
Á. FRIÐRIKSSON
ASSISTÉ PAR
F. R. HARDEN JONES

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

MARS 1959

IMPRIMÉ AU DANEMARK
ANDELSBOGTRYKKERIET I ODENSE

Åge Vedel Tåning
1890—1958

THE death of Dr. phil. ÅGE VEDEL TÅNING, the President of the Council, cast a shadow over the 46th Statutory Meeting of the International Council for the Exploration of the Sea, which was held in Copenhagen from 29. September to 4. October, 1958. Dr. TÅNING passed away on Friday, 26. September. At the death of Professor H. U. SVERDRUP in 1957, it became the duty of Dr. TÅNING, being the First Vice-President of the Council, to act as President, until he was

elected President at the 45th Meeting of the Council in 1957. It is extremely regrettable that the Council should not enjoy his able presidency for more than one year.

Å. VEDEL TÅNING was born in Copenhagen on 27. July 1890. He took his degree as teacher from a Training College in 1911 and received the Higher School Certificate in 1913. In 1920 he took his degree at the University of Copenhagen and in 1929 he obtained his doctorate from the same University. He had the opportunity, in 1923–1924, to spend a few months at the "Institut Océanographique" in Monaco.

The turning point in VEDEL TÅNING's life was, without doubt, when he first became associated with Professor Johannes SCHMIDT in 1916. His co-operation with this celebrated scientist lasted until Professor SCHMIDT died in 1933 and led TÅNING to devote his entire life to marine research. In 1920–1922 he participated in the Dana-Expedition to the North Atlantic and Gulf of Panama, and in 1928–1930 he also participated in the Carlsberg Foundation's Oceanographical Expedition round the world. In addition, he was the leader of numerous research cruises with the "Dana" and other vessels in the North Atlantic and the North Sea, the first of which took place in 1924. During one of these cruises in 1935, a trawler collided with the "Dana" which went down and on this occasion TÅNING lost some valuable papers and manuscripts, that he was preparing for publication.

In 1918 Å. VEDEL TÅNING was appointed SCHMIDT's assistant to the Danish Commission for Fisheries and Marine Research. Later he was also appointed a member of the Commission and from 1951 he acted as Vice-Chairman. From 1935 to 1951 he was responsible for the Danish Fisheries investigations in the North Sea and northern waters. Finally, in 1951, TÅNING was nominated Director of all Danish fisheries investigations, which, from 1952, were centralized in the "Danish Institute for Fisheries and Marine Research". In 1933, he succeeded SCHMIDT as Director of the large collections, brought back from the numerous expeditions and as Editor of "The Carlsberg Foundation's Oceanographical Expedition round the World 1928–1930" and previous "Dana" expeditions.

In spite of the heavy responsibility of many and difficult tasks in the field of marine research and administration which rested on TÅNING, his activities were by no means limited to marine investigations. He was also an outstanding ornithologist and participated wholeheartedly in the preservation of animal life. Nothing describes better his wide scope of activity than the fact that he was a member of the "Danish Commission for the Protection of Nature", of the "Comité de Perfectionnement de l'Institut Océanographique de Paris", and of the "International Committee for Bird Preservation". He was corresponding member of the "Zoological Society of London" and of "La Société d'Etudes Océaniennes" and he was Honorary Member of the "American Society of Ichthyologists and Herpetologists", of

the "Fiskifélag Islands" (The Fisheries Association of Iceland), and of the "Marine Biological Association of the United Kingdom".

The International Council for the Exploration of the Sea is greatly indebted to VEDEL TÅNING for his long and valuable services. He served as Danish Expert in 1931, 1933–1939, and 1945. From 1947–1957 he was Danish Delegate (suppleant in 1947), and from 1952–1955 he acted as Vice-President on the Bureau. From 1955–1957 he was First Vice-President, and finally he was President from 1957 until his death. He was Chairman of the North-Western Area Committee for more than 20 years (1933–1954) and of the Distant Northern Seas Committee from 1954 until he was elected President. In his capacity of Chairman of the North-Western Area Committee he was also Chairman of the Faxa Bay Sub-Committee and of the Sub-Committee on the Faroe Question. Both these tasks were time-demanding and difficult.

During his long participation in the Council's work, TÅNING devoted himself keenly to its problems. Through tagging experiments he contributed largely to our knowledge of the migrations of different species of fish, especially cod and flatfish. He carried out fundamental experiments in order to elucidate racial problems and he made a survey of the distribution of redfish in the North Atlantic and promoted large-scale stock analyses of important species. When dealing with biological problems, he never forgot the essential importance of environmental factors, such as temperature, salinity, etc., although, in his mind, problems relating to the fishery should have first priority. He clearly realized the importance of the increased temperatures in Arctic waters and it was on his initiative that a symposium on this matter was held in 1948 and that a bibliographical survey was compiled. It must also be mentioned that he was the first to draw up a long-term research programme to be applied by the North-Western Area Committee.

The great number of papers written by him indicate that several fields of marine research benefited from his activities. His Doctor's Thesis in 1929 dealt with "Plaice Investigations in Icelandic Waters" and many other papers concerning fish stocks were written by him. He also wrote a number of papers on markings of fish, migrations, fluctuations, systematics, and research techniques etc., the names of which it is impossible to list here. Besides this he acted as Editor of several long series of works, such as the *Dana-Reports*, as mentioned earlier, the "Report of the Sub-Committee on the Faxa Bay", and the 3rd volume of LEHN SCHIØLER's large work on the birds of Denmark, etc.

Several orders were awarded him in recent years. He was Commander of (1) The Danish Order of Dannebrog, (2) The Icelandic Falcon Order, (3) The Norwegian St. Olaf's Order, and (4) The Swedish Nordstjerne Order. He was also Officer of the Dutch Oranje-Nassau Order and of the French Mérite Maritime.

During the greatest part of his life Å. VEDEL TÅNING was overburdened by duties. Actually he was not very fond of administration, but he was a person with a strong sense of duty. Owing to his high standard of culture, knowledge, and goodwill many tasks were entrusted to him, and he always gave his whole mind to his duties. He possessed the valuable human quality of being perfectly honest in his work as scientist, in his administrative duties, and in all other relations. Those who had the privilege to know Å. VEDEL TÅNING personally and to co-operate with him will always remember his charming and helpful personality. He will be deeply missed by his wife, Anna Margrethe TÅNING, by his two children, and by his many friends.

Árni Friðriksson

The Seasonal Incoming Radiation in Norwegian and Arctic Waters, and Indirect Methods of Measurement[1])

By

Theodore J. Smayda

Institute for Marine Biology, Sect. B, University of Oslo, Norway

THE importance of light in governing primary production in the sea has been well documented. Furthermore, it is common knowledge that the amount and quality of light reaching a cell surface is a function of many physical determinants which reflect, scatter, or absorb radiation causing an attenuation with depth. Measurements of this energy are easily made by any of a variety of instruments now available (LUND and TALLING, 1957), or indirectly by employing a formula.

KIMBALL (1928) calculated the average daily totals of solar radiation (Q) reaching the sea surface at different latitudes by the formula:

$$Q = Q_0 \, (0{\cdot}29 + 0{\cdot}71 \, [1{\cdot}0 - C]) \text{ g cal. per cm}^2 \text{ per day} \qquad (1)$$

where Q_0 represents total radiation assuming a clear sky and C is the proportion of the sky covered by clouds.

MOSBY (SVERDRUP, 1953) also derived a formula to estimate incoming radiation ($\bar{I}_0$):

$$\bar{I}_0 = 0{\cdot}026 \, (1 - 0{\cdot}075 \, \bar{C}) \, \bar{h} \text{ g cal. per cm}^2 \text{ per min.} \qquad (2)$$

where $\bar{C}$ is the average cloud cover on the scale 0–10 and $\bar{h}$ is the average altitude of the sun. The constant (0·026) expresses the atmospheric turbidity at 60°N; at 70°N it becomes 0·027 (SVERDRUP, JOHNSON, and FLEMING, 1942).

Incoming total (global) radiation (G_H^N) can also be calculated by WERNER JOHANNESSEN's (1956) formula:

$$G_H^N = \bar{C}_H \cdot \bar{G}_H \text{ k cal. per m}^2 \text{ per day} \qquad (3)$$

where $\bar{C}_H$ is a cloud factor expressing the relationship between cloud cover and radiation as found at Bergen, Norway and is defined as:

$$\bar{C}_H = 1{\cdot}339 - 0{\cdot}1073 \cdot \bar{N} \qquad (4)$$

[1]) Contribution No. 964 from the Woods Hole Oceanographic Institution.

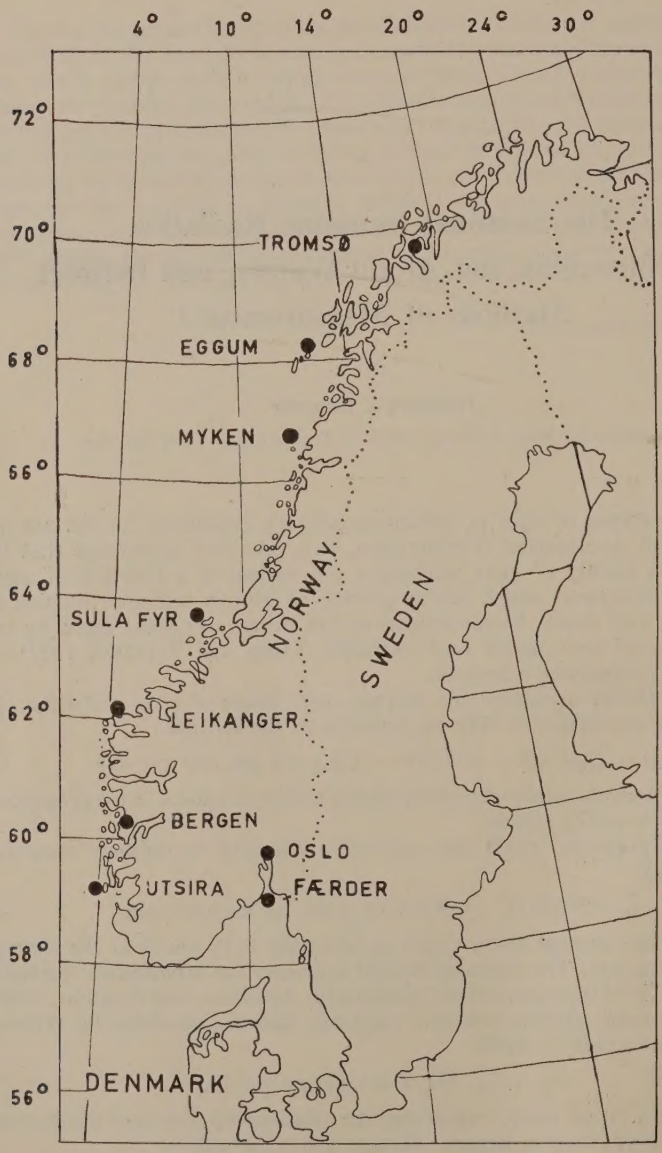

Figure 1. Sites along the Norwegian coast where the seasonal radiation cycle has been calculated.

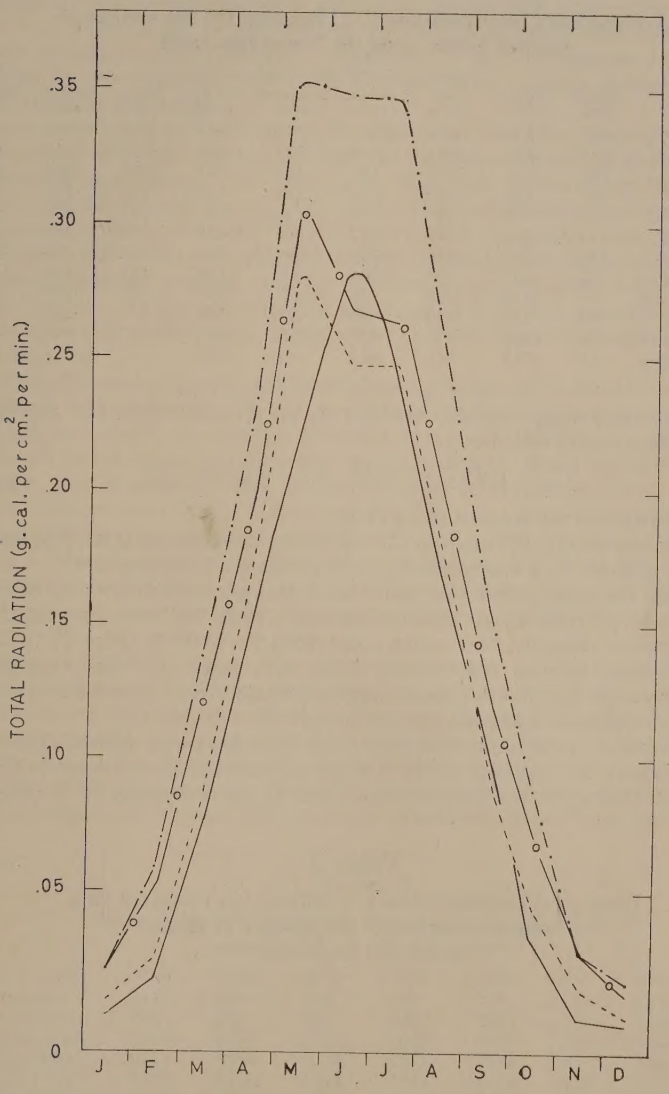

Figure 2. Seasonal radiation cycle at selected points along the Norwegian coast.

——— · ——— Færder 59°N
——— ○ ——— Utsira 59°N
· · · · · · · · · Sula Fyr 64°N
——————— Eggum 68°N

Table 1

Average daily total radiation (G_H^N) reaching the sea surface at selected points along the Norwegian coast

(g cal. per cm² per min.)

Date	Færder 59°N	Utsira 59°N	Oslo 60°N	Bergen 60°N	Leikanger 62°N	Sula Fyr 64°N	Myken 66°45′N	Eggum 68°N	Tromsø 70°N
19. January ...	·021	·022	·019	·021	·014	·009	·004	·002	–
13. February ..	·057	·052	·051	·049	·041	·025	·019	·016	·013
17. March	·144	·119	·132	·119	·121	·083	·078	·076	·069
16. April	·233	·196	·202	·174	·185	·170	·164	·152	·147
15. May	·352	·304	·297	·290	·316	·280	·257	·225	·199
10. June	·347	·268	·293	·277	·305	·248	·279	·281	·278
19. July	·346	·262	·275	·256	·300	·248	·262	·244	·271
17. August....	·252	·198	·208	·204	·224	·180	·181	·165	·161
17. September.	·157	·126	·128	·118	·121	·098	·095	·107	·095
14. October...	·088	·070	·079	·069	·066	·044	·037	·033	·027
15. November.	·028	·028	·023	·026	·019	·014	·007	·005	·003
11. December .	·016	·013	·011	·012	·008	·004	–	–	–

where $\overline{N}$ is the average monthly cloud cover on the scale 0–10. For any given day the relationship becomes:

$$\overline{C}_H = 0{\cdot}950 - 0{\cdot}0237 \cdot N_d - 0{\cdot}00907 \cdot N_d^2 \qquad (5)$$

where N_d represents the mean cloud cover.

The expression $\overline{G}_H$, in equation (3), represents the mean total daily radiation (direct + diffuse) on a horizontal surface assuming a cloudless sky.

Inserting the mean monthly cloud covers for the period 1941–1950 in WERNER JOHANNESSEN's formula, the seasonal radiation cycle has been calculated for selected points along the Norwegian coast from 59° to 70°N (Figs. 1, 2; Table 1). The values for $\overline{G}_H$, representing those days when the solar declination corresponded to the monthly mean, were abstracted from WERNER JOHANNESSEN's report and are presented here in tabular form (Table 2).

The decrease in radiation with increasing latitude is well defined (Table 1). Comparison of the seasonal cycles at Færder located at the entrance to Oslo-fjord, and Utsira, on the western coast, both at approximately 59°N (Fig. 1),

Table 2

Daily total radiation (direct + diffuse) ($\overline{G}_H$) received on a horizontal surface in the absence of clouds

(k cal. per m² per day)

Date	59°N	60°N	62°N	64°N	66°N	68°N	70°N
19. January	565	480	325	185	115	40	–
13. February	1305	1210	960	785	575	430	305
17. March	3030	2910	2665	2430	2160	1975	1720
16. April	4895	4785	4610	4400	4210	4100	3885
15. May	6320	6195	6160	6080	5875	5835	5750
10. June	7075	7035	6960	6975	7015	6875	6945
19. July	6550	6390	6310	6320	6180	6205	6195
17. August.....	5140	5000	4950	4765	4550	4455	4265
17. September.....	3460	3310	3195	2940	2635	2450	2165
14. October.....	1970	1890	1650	1405	1175	950	790
15. November.....	775	660	510	360	205	130	65
11. December	370	320	200	100	25	–	–

reveals the importance of cloud cover in determining the amount of incoming radiation. The occurrence of a maximum energy flux during May between 59° and 64°N (Table 1) results from reduced cloud cover. Although the daily total radiation under cloudless conditions is at a maximum during June (Table 2), the observed cloud cover is from 1·0 to 1·5 units greater than that prevailing during May.

The development of the spring phytoplankton along the Norwegian coast is coincident with the marked increase in radiation occurring during March (Braarud and Bursa, 1939; Braarud, Gaarder, and Nordli, 1959; Føyn, 1929; Gaarder, 1938; Gran, 1927, 1929). This flowering begins approximately a month earlier at 59°–60°N than at 68°–70°N. In general, the radiation is between 0·090–0·100 g cal. per cm^2 per min. at this growth phase, and maximum abundance is not attained until the intensity is approximately 0·150 g cal. per cm^2 per min. As the conditions of turbidity and stability influence the light-phytoplankton relationship, deviations from the above correspondence can be expected.

Using Mosby's formula, results in close agreement with those obtained with Werner Johannessen's formula are found for cloud covers greater than 6·5 on the scale 0–10, the average difference being only 0·005 g cal. per cm^2 per min. At cloud covers less than 6·5, Mosby's formula gives significantly lower results, the divergence being inversely related to the degree of cloud cover. At a cloud cover of 5·0 the difference was 0·030 g cal. per cm^2 per min., and the mean difference between 5·0 and 6·5 was 0·016 g cal. per cm^2 per min. Kimball's formula consistently gave lower results than the other two, especially during the period April–August when differences greater than 0·050 g cal. per cm^2 per min. were common; the mean difference for the other months was only 0·009 g cal. per cm^2 per min.

The purpose of this note is to depict the seasonal radiation cycle along the Norwegian coast, and to present data enabling the calculation of incoming radiation on the sea surface between latitudes 59° and 70°N. Should Mosby's formula be used, the appropriate solar altitude can be obtained from a nautical almanac or through interpolation of the rather incomplete data presented here (Table 3), condensed from Werner Johannessen's tables. Should Werner Johannessen's or Kimball's formula be employed, Table 2 can be consulted

Table 3

Mean solar altitude ($\bar{h}$) on days when solar declination corresponds to monthly means

Date	59°N	60°N	62°N	64°N	66°N	68°N	70°N
19. January	2·0	1·8	1·2	0·9	0·5	0·2	–
13. February	4·2	3·9	3·3	2·8	2·2	1·7	1·2
17. March	9·0	8·7	8·1	7·5	6·9	6·3	5·6
16. April	14·7	14·5	14·3	13·5	13·0	12·4	11·9
15. May	19·8	19·6	19·3	19·0	18·7	18·5	18·4
10. June	22·1	22·4	22·2	22·0	22·0	22·1	22·3
19. July	21·1	21·0	20·7	20·5	20·3	20·3	20·4
17. August	16·7	16·4	16·0	15·5	15·1	14·7	14·2
17. September	10·9	10·7	10·1	9·4	8·9	8·2	7·7
14. October	6·3	6·0	5·3	4·7	4·2	3·5	3·0
15. November	2·6	2·3	1·8	1·4	0·9	0·5	0·2
11. December	1·4	1·1	0·8	0·4	0·06	–	–

to obtain incoming radiation for a *cloudless sky* anywhere between 59°–70°N. These data, then, make it necessary to know only the degree of cloudiness for the area in question.

Although here the data are applied to Norwegian coastal waters, they have also been used to estimate incoming radiation within the Norwegian Sea around Jan Mayen Island (SMAYDA, 1958). SVERDRUP (1953) outlines a procedure to calculate the amount of light reaching any depth after knowing the incoming radiation and extinction coefficient of the water mass. The values obtained by indirect measurements represent total radiation, whereas the radiation active in photosynthesis, that in the spectral region 400–700 mμ, represents an average fraction of 0·46 of the total energy (TALLING, 1957).

While direct measurements of radiation should be made when possible, indirect measurements yield results of considerable accuracy (KIMBALL, 1928) that can be used with profit.

Summary

1. The seasonal radiation cycle along the Norwegian coast has been calculated for nine localities between latitudes 59°–70°N by means of WERNER JOHANNESSEN's formula. It has been found that the incoming radiation amounts to 0·090–0·100 g cal. per cm^2 per min. when the phytoplankton initiate their spring development; maximum abundance is obtained when incident radiation is approximately 0·150 g cal. per cm^2 per min.

2. A comparison has been made of radiation estimates by three different formulae, and data have been presented enabling the calculation of incoming radiation between latitudes 59°–70°N.

References

BRAARUD, T., & BURSA, A., 1939. "The phytoplankton of the Oslofjord 1933–1934". Hvalråd. Skr. norske VidenskAkad., 19: 1–63.

BRAARUD, T., GAARDER, K. RINGDAL, & NORDLI, O., 1959. "Seasonal changes in the phytoplankton at various points off the Norwegian west coast". (In press.)

FØYN, B. R., 1929. "Investigation of the phytoplankton at Lofoten March–April, 1922–1927". Skr. norske VidenskAkad., I mat.-nat. Kl. 1928, 10: 1–71.

GAARDER, K. RINGDAL, 1938. "Phytoplankton studies from the Tromsø district 1930–31". Tromsø Mus. Aarsh., **55**: 1–159.

GRAN, H. H., 1927. "The production of plankton in the coastal waters off Bergen March–April 1922". Rep. Norweg. Fish. Invest., **3** (8): 1–74.

GRAN, H. H., 1929. "Investigation of the production of plankton outside the Romsdalsfjord 1926–27". Rapp. Cons. Explor. Mer, **56**: 1–112.

KIMBALL, H. H., 1928. "Amount of solar radiation that reaches the surface of the earth on the land and on the sea, and methods by which it is measured". Monthly Weather Rev., **56**: 393–98.

LUND, J. W. G., & TALLING, J. F., 1957. "Botanical limnological methods with special reference to the algae". Bot. Rev., **23**: 489–583.

SMAYDA, T. J., 1958. "Phytoplankton studies around Jan Mayen Island, March–April, 1955". Nytt Mag. Bot., **6**: 75–96.

SVERDRUP, H. U., 1953. "On conditions for the vernal blooming of phytoplankton". J. Cons. int. Explor. Mer, **18**: 287–95.

SVERDRUP, H. U., JOHNSON, M. W., & FLEMING, R. H., 1942. "The Oceans". Prentice-Hall Inc., New York.

TALLING, J. F., 1957. "Photosynthetic characteristics of some fresh water plankton diatoms in relation to underwater radiation". New Phytologist, 56: 29–50.

WERNER JOHANNESSEN, T., 1956. "Varmeutvekslingen i bygninger og klimaet". Rapp. Norges Byggforskningsinst., 21.

The Role of Microorganisms in the Primary Production of the Black Sea

By

A. E. Kriss

Institute of Microbiology, USSR Academy of Sciences, Moscow

Introduction

It is usually considered that in the seas the main producer of organic matter is the marine vegetation: phytoplankton and phytobenthos. The Black Sea is an example of a water body in which the primary production of organic matter by autotrophic bacteria considerably exceeds that by plants.

For several years the Department of Marine Microbiology, Microbiological Institute, USSR Academy of Sciences, has been carrying out investigations of the vertical distribution of the number and biomass of microbe populations in various seas and oceans (Kriss, 1954, 1955, 1956; Kriss and Biriuzova, 1955).

These investigations are made by methods of direct counting under a microscope rather than by culture techniques, so that all the population is taken into account, and not only the microbe species which propagate in the laboratory media and make only one per cent., or less, of the total mass of microorganisms living in the seas and oceans. It is true that methods of direct microscopy are not yet accurate enough because of the difficulties in identifying small bacterial cells and dead organisms, but already now they are more accurate than other methods of quantitative analysis used by microbiology, hydrobiology, and ichthyology.

Number and Biomass of Microorganisms in Different Seas

Table 1 summarizes data on an average number and biomass of microorganisms at various depths of the Caspian and Black Seas, north-western part of the Pacific Ocean, and in the region of the North Pole.

The samples taken at the microbiological stations in these seas and oceans were made at the same conventional levels; therefore it was possible to draw a

Table 1

Average number and biomass of microorganisms at different sea and ocean depths

Layers of water in m	Southern part of the Caspian Sea			Middle part of the Caspian Sea			The Black Sea[1])		The Pacific Ocean			The North Pole[2])	
	Number of stations	Number of bacteria, in thousands per ml	Biomass (mg/m³)	Number of stations	Number of bacteria, in thousands per ml	Biomass (mg/m³)	Number of bacteria, in thousands per ml	Biomass (mg/m³)	Number of stations	Number of bacteria, in thousands per ml	Biomass (mg/m³)	Number of bacteria, in thousands per ml	Biomass (mg/m³)
0–50	9	224	44·8	7	136	27·2	167	33·6	9	125	25	9	1·8
50–100	6	52	10·4	5	39	7·7	38	7·7	9	53	10·5	6	1·2
100–200	3	19	3·8	4	17	3·4	54	19·7	9	26	5·1	3	0·6
200–500				3	5·5	1·1	69	32·0	9	6	1·1	0·6	0·1
500–750				1	1	0·2	65	38·6	9	1·2	0·24	0·2	0·05
750–1000							61	41·0	9	2	0·45	0·5	0·1
1000–1500							56	44·2	9	1·9	0·4	0·6	0·12
1500–2000							58	43·1	9	1·4	0·3	0·4	0·08
2000–3000									10	0·4	0·08	0·15	0·03
3000–4000									9	0·3	0·05		
4000–5000									5	0·2	0·03		
5000–6000									2	0·04	0·009		
6000–7000									2	0·06	0·01		
7000–8000									1	0·08	0·02		
8000–9000									1	0·04	0·008		

[1]) An average of five stations.

[2]) Average of two stations.

comparison between the numbers of bacteria found at the same depths of different water-body types.

The Black Sea is a continental deep water body which has unique hydrographical, hydrochemical, and hydrobiological conditions. The cross section of this water body can be divided into two layers of unequal thickness. The upper layer is thin and contains oxygen and consequently flora and fauna. It extends from the surface to the depth of 125 to 225 m. The lower layer, which at some places extends to the depth of 2,000 m, is contaminated by hydrogen sulphide and is populated only by microorganisms.

The Caspian Sea is the largest lake, up to 1000 m deep.

The regions of the Pacific Ocean around Kamchatka and the Kurile Islands are interesting because here there is one of the deepest depressions in the oceans with depths up to 10,000 m.

The Arctic Ocean in the region of the North Pole is part of the polar basin with abyssal depths buried under pack ice. It is far from land.

As is evident from Table 1, the average density and biomass of the microbes are different at the same depths in different areas. The highest concentration of microbes in the photosynthetic zone (0 to 50 m) is found in the southern part of the Caspian Sea, then in the Black Sea, the middle part of the Caspian Sea, and, finally, in the regions of the Pacific Ocean around the Kurile Islands and Kamchatka. But everywhere, except the region of the North Pole, the number of microorganisms in the photic zone varies from 125 to 225 thousand bacteria per ml or from 25 to 45 mg/m³ of water. There is clearly a scarcity of microbes in the central arctic regions, although the microbiological investigations were

carried out when the summer was at its height. Here the number and biomass of microorganisms is one order of magnitude less than in the other areas.

In the deeper water layers (50–100 m or 100–200 m) the concentration of microbes is already decreased to tens of thousand per ml and the biomass to several mg/m^3 and never more than 10 mg/m^3. This can be seen in the Caspian Sea and in the Pacific Ocean. In the Black Sea, in the layer between 100 and 200 m, one can already see the anomaly in the vertical distribution of microorganisms caused by the proximity of the hydrogen sulphide zone: the number, and especially the biomass, of the microbes increases. In the Arctic Ocean, not far from the North Pole, the density of microbes does not decrease as much as it does in other normal seas and oceans, but nevertheless here too it is one order of magnitude lower.

It is interesting to note that in the layers of 200–500 m and 500–750 m the number and biomass of microorganisms in the Caspian Sea and in the Pacific Ocean are much the same: 1,000 and 6,000 bacteria respectively per ml, or 0·2 to 1·0 mg/m^3. Near the North Pole the change in abundance of microorganisms with depth is less when compared with the Caspian Sea and the north-western part of the Pacific Ocean. In the Pacific Ocean in the water layers of 750–3,000 m depth the number of bacteria is already measured in thousands per ml, while the biomass is down to 0·1 to 0·01 mg/m^3. In the central regions of the Arctic Ocean the number and biomass of microorganisms is only by three to four times lower. In the very deep water of the Pacific Ocean, close to the maximum depths, the number of microorganisms is expressed in tens per ml, while the biomass is at the order of 0·01 to 0·001 mg/m^3.

Organic Matter Available for Assimilation

The vertical distribution of the number and biomass of microorganisms in the normal type of marine basins is determined by the availability of organic matter in the forms accessible for assimilation. The application of chemical methods to determination of organic matter in the water has only revealed that its concentration is not considerably varied with depth. This picture was made essentially more detailed by microbiological investigations. It appeared that in the first approximation organic matter in the sea can be qualitatively divided into the following three groups.

1. Autolysing remains of plant and animal organisms which are at the first stages of degradation and therefore easily accessible to those heterotrophic microorganisms which are capable of developing in the laboratorial media of analogous composition (pepton media). The distribution of these remains in the sea from the surface to the bottom is of a patchy (occasional, not regular) character, which accounts for the non-uniformity, or microzonality in the distribution of the so-called saprophytic microorganisms, i.e., bacteria propagating in proteinous media.

2. Organic matter which has already undergone a series of transformations and is accessible principally to those microbes which cannot propagate in the usual nutrient media used in microbiological experiments. These forms of organic matter are mainly concentrated in the zone of photosynthesis where there are considerable amounts of exchange and disintegration products of the plant and animal plankton. This explains the high density of microbes in the surface layers which is very pronounced in the thermocline.

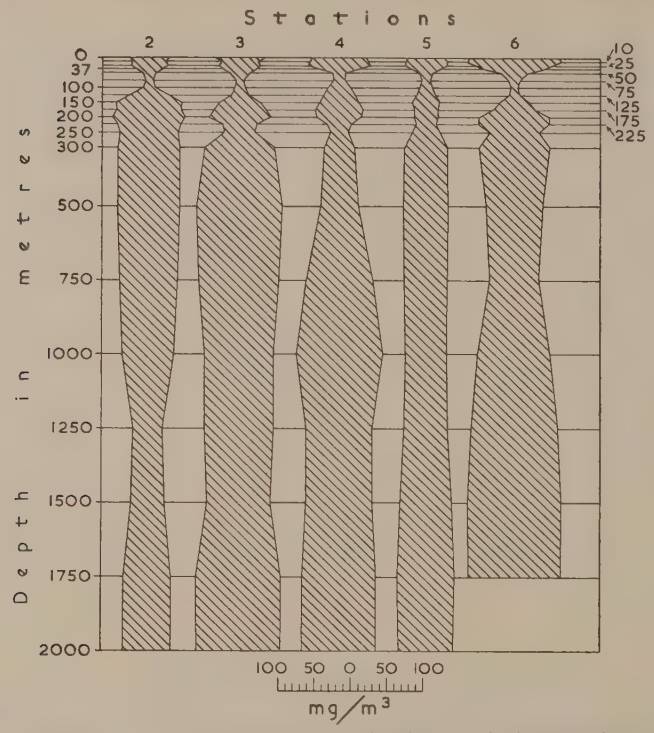

Figure 1. Vertical distribution of the biomass of microorganisms in the Black Sea.

3. Water humus, forms of organic matter which are difficult to decompose by microorganisms. This forms the bulk of the organic material below the photosynthetic zone and leads to a reduction in the number and biomass of microorganisms in the whole body of normal water basins from the level of 50 to 75 m to the bottom.

In the oxygen zone of the Black Sea the character of vertical distribution of the biomass of microorganisms in summer, when there is no vertical circulation and storms, is the same as that in other seas. The highest values are characteristic of the surface layers, especially of the layer of thermocline and a little lower.

In the layers deeper than 50 m there is a decrease in the biomass of bacteria (Fig. 1), but at the upper boundary of the hydrogen sulphide zone, at a depth of 125–150–200 m, the biomass of microorganisms begins to increase. In the hydrogen sulphide zone the biomass varies comparatively little in the layer from 200–300 m down to the bottom at 1750–2000 m. But the most important and characteristic feature of the Black Sea is the considerably larger average biomass of microorganisms in the hydrogen sulphide zone compared with the oxygen zone.

In normal seas the biomass at a depth of 200 m to the bottom is several hundred or even several thousand times less than that in the surface layers

but in the Black Sea a cubic metre of water taken from 200–2000 m depth contains, on an average, 1·5–2 times the biomass of microorganisms found in a cubic metre of water taken from the layer of 0–200 m depth. It is equal to 32–43 mg/m^3.

Purple Sulphur Bacteria in the Depths of the Black Sea

The large biomass of microorganisms in the hydrogen sulphide zone is due to filamentous bacteria which are distinguished by their fragmentation (Fig. 2).

To study the biology of these microorganisms, 20–100–250 ml flasks with ground glass stoppers were filled up to the stopper with water samples taken at a number of deep-water stations in the years 1950, 1951, and 1952 in various regions of the Black Sea, 40–80 miles off the shore. Following 1–2 or more months of storage of the flasks at room temperature and in daylight, a reddish sediment or areas with red spots appeared at the bottom of some of the flasks. The water in some flasks also turned pink or red. Prolonged storage of the flasks (over a year) with coloured sediment resulted in gradual disappearance of the sediment which finally became colourless; the same thing happened to the flasks which were opened in order to take some water away.

As is shown in Table 2, the appearance of the pink-red sediment was observed only in those flasks which contained water samples from different depths within the Black Sea hydrogen sulphide zone. This phenomenon was not observed in the water samples taken from the oxygen zone of the Black Sea. We are not sure that the absence of the red sediment in some flasks filled with water from certain depths or in replicas from a given depth, is due only to the

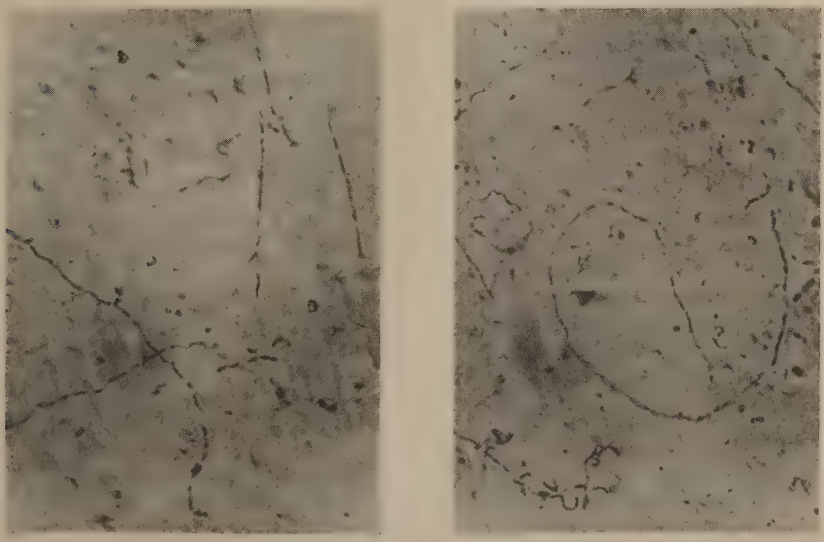

Figure 2. Filamentous forms of microorganisms in the Black Sea.

Table 2

Growth of the purple sulphur bacteria in flasks containing water samples taken from various depths in the Black Sea

\+ appearance of pink-red sediment.
− absence of coloured sediment.

Figures in parentheses show the number of flasks with positive or negative results.

Station	6	2	3	4	5	6	2
Date	1950	1951	1951	1951	1951	1951	1952
No. of flasks filled	1	1	1	2	3	3	3
Depth, m							
0							−(3)
25							−(3)
50							−(3)
75							−(3)
100							−(3)
150							−(3)
200							+(1)
250							−(3)
300							+(1)
500	−(1)	+(1)	−(1)	+(1)	+(1)	−(3)	+(2)
750	−(1)	−(1)	−(1)	+(1)	+(2)	+(2)	+(3)
1000	−(1)		+(1)	+(2)	+(3)	−(3)	−(3)
1250	−(1)		+(1)	+(2)	+(3)	+(1)	+(2)
1500	+(1)		+(1)	−(2)	+(1)	+(3)	+(1)
1750	+(1)		−(1)	−(2)	−(3)	−(3)	−(3)
2000	−(1)		+(1)	−(2)	+(3)		−(3)
Slime	+(3)						

microzonality in the distribution of the microorganisms responsible for the formation of this sediment as a result of their propagation. It is also possible that conditions may drastically change when filling the flasks, in particular, the water sample concentration of hydrogen sulphide which is indispensable for the life activity of these microorganisms.

By means of trans-inoculations into Lehner and Van-Niel media, accumulative cultures of the purple microorganisms of the second order were obtained, since we consider the formation of the red sediment in flasks with water samples may possibly be an example of the primary accumulation of a marked amount of biomass of the given microorganisms under conditions as much as possible approximating those of their habitat.

It should be pointed out that not all the cases of trans-inoculations from the flasks containing pink-red sediment into the Lehner and Van-Niel media, or the subsequent trans-inoculations of the cultures from the Lehner medium onto the Lehner medium or from the Van-Niel medium onto the Van-Niel medium, gave positive results. Perhaps these "caprices" (absence of growth) of the cultures may be accounted for by too small amounts of the inoculation material, particularly in cases when inoculations were made not in laboratory test-tubes but in flasks containing large volumes of nourishing medium; this may be due also to the inconsistency of the latter with regard to the oxidation-reduction potential required for propagation of the purple microorganisms.

Microscopic examination of the cultures of different age in Van-Niel and Lehner media showed that two-week and four-week cultures were composed of stick-shaped cells of various length, both straight and curved, with inclusions in the plasma, strongly refracting light. The appearance of typical filamentous forms was observed in older cultures, the amount of the former may be considerable.

Table 3

Comparative quantitative characteristics of a biomass of microorganisms, phytoplankton and zooplankton in the Black Sea

	Average biomass mg/m³	Average biomass under 1 m² of sea surface in g	Total biomass of the Black Sea, in million tons[3])
Microorganisms (Oxygen zone)			
0–200 m	20		1·3
Microorganisms (Hydrogen sulphide zone)		74	
200–2000 m	40		18·5
Phytoplankton[1])			
0–200 m	59	11·6	4·0
Zooplankton[2])			
0–200 m	184	36·8	12·4

[1]) Data obtained by Morozova-Vodianitskaya (1950).
[2]) Data obtained by Kusmorskaya (1950).
[3]) According to Shockalsky, Snezhinsky, and Chizhickov, water volume is 67,594 km³ in the oxygen zone and 462,360 km³ in the hydrogen sulphide zone (Zenkevitch, 1947).

Experiments to find out the capacity of these microorganisms to oxidize hydrogen sulphide (Kriss and Rukina, 1953) convinced us that they are sulphuric bacteria. Using the Van-Niel medium, cultures of purple microorganisms taken from deep water in the Black Sea showed a 4 to 14 times decrease in concentration of hydrogen sulphide as compared with the control. In some cases the hydrogen sulphide was all used up. These purple sulphuric bacteria, which are found throughout the Black Sea hydrogen sulphide zone, form in the cultures not only carotinoid pigments, but also bacteriochlorophyll with absorption maxima in methyl alcohol varying from 775 to 770 mμ (chief maximum) and from 610 to 611 mμ.

As is known, hydrogen sulphide gives hydrogen to purple sulphuric bacteria in the process of carbon dioxide assimilation. This process is photosynthetic because it develops due to the energy of the sun. But in the deep water of the Black Sea where no light penetrates there should be another source of energy for purple sulphuric bacteria living in the water contaminated by hydrogen sulphide in order that they could reduce carbon dioxide. This source could be the organic matter in the sea water or radioactive disintegration.

We are in favour of the latter and assume that the energy of radioactive disintegration can be consumed by microorganisms and be used for decomposing carbon dioxide. The organic matter of the sea water in the hydrogen sulphide zone is hardly important because in the deeper water of the Black Sea it is mainly represented by water humus which is difficult to assimilate by microorganisms.

This process of autotrophic development of microorganisms, which by the supposed energy source may be analogous to photosynthesis and chemosynthesis, may be given the name of radiosynthesis, leads to accumulation of an enormous microbic biomass in the hydrogen sulphide zone of the Black Sea. In the deep water areas which are predominant in the Black Sea (Archangelsky and Strachov, 1938), microorganisms have a biomass under 1 m² of the sea surface which is 1·5 times larger than the total biomass of phytoplankton and zooplankton (Table 3). In the whole Black Sea, if we take only rough figures, the biomass of microbic plankton is greater than any of the other types of plankton.

Table 4

Vertical distribution of the number of filamentous bacteria in the Black Sea

(Jalta-Batumi Cross Section, February)

Stations	II	III	IV	V	VI	VII
Distance from Jalta in miles	38	115	180	240	305	367
Depths in m 0.....	30	400	10	0	0	0
10.....	30	20	0	20	0	0
25.....	0	20	10	20	0	0
37.....	40	0	40	20	20	10
50.....	90	0	50	60	0	0
75.....	100	60	90	50	20	40
100.....	0	20	70	0	30	50
125.....	1000	900	20	100	10	20
150.....	4000	400	2600	1200	800	20
175.....	9800	–	3700	2100	2800	500
200.....	8100	6000	4400	600	4100	1900
225.....	7900	7000	2800	2300	6800	3200
250.....	5000	40	20	120	4000	4100
300.....	6500	7000	2600	2900	4500	4400
500.....	7800	10,000	2900	4200	5600	–
750.....	7600	10,000	4000	4200	4400	–
1000.....	8800	9000	9500	5200	6000	–
1250.....	5300	9000	8400	4800	10,400	–
1500.....	6200	10,000	7500	6200	8800	–
1750.....	5000	8000	8800	5700	8900	–
2000.....	6600	15,000	7400	7000	–	–

It should be mentioned that large numbers of filamentous microorganisms live only in the hydrogen sulphide zone of the Black Sea (Table 4). Within the hydrogen sulphide zone their concentration is very large and constitutes many thousand per ml of water. As a rule there are only small numbers in the oxygen zone. These filamentous microorganisms probably come from hydrogen sulphide zone and occasionally get into the oxygen zone when there is intensive turbulence. This is shown by the following comparative investigations carried out in June and February at the same place of the Black Sea at a station situated 30 miles off shore. The number of microbes at different depths of the oxygen zone down to 200 m from the surface was determined. It appeared that in winter the microbic mass is sharply increased in the lower layers of the oxygen zone due to filamentous microorganisms from the hydrogen sulphide zone. As a result of a long vertical circulation caused by strong surface cooling, the inflow of water from the hydrogen sulphide zone with their characteristic microbes is so large that their density in winter at the depths of 125 and 150 m is much greater than during the summer (Fig. 3). Thus the organic matter newly formed in the hydrogen sulphide zone of the Black Sea in the form of autotrophic microorganisms participates, due to water exchange between the hydrogen sulphide and oxygen zones, in the processes (food relations in particular) which take place in the oxygen zone. According to LEBEDEVA (1953), the vertical circulation is more intensive in winter, and the biomass of microorganisms is increased in the lower layers of the oxygen zone due to the translocation of filamentous bacteria, autotrophs from the hydrogen sulphide zone, in amounts up to 53 mg/m^3. This biomass is larger than that of *Calanus* which

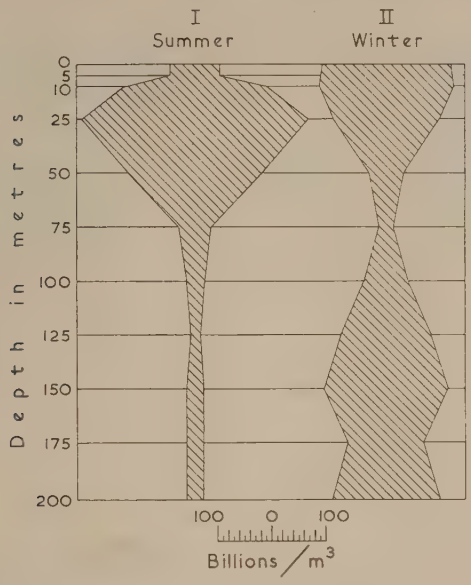

Figure 3. Vertical distribution of the density of the bacterial population in the oxygen zone of the Black Sea in winter and summer at a station 30 miles from land.

for most part of a 24 hours period is found in the lower levels of the oxygen zone where a large biomass of bacteria is available. It is quite possible that filamentous microorganisms are used as food by *Calanus* because LEBEDEVA found them in the intestinal tract of this species.

The data cited show how great is the role of microorganisms in the primary production of organic matter in the Black Sea. If, out of the biomass of autotrophic bacteria we take only the biomass of filamentous microorganisms and compare it with the biomass of phytoplankton in the Black Sea, it appears that the biomass of filamentous bacteria (33 mg/m^3 × 462,360 km^3 of the hydrogen sulphide zone) is more than 15,000,000 tons, that is, almost 4 times larger than the biomass of phytoplankton (59 mg/m^3 × 67,594 km^3 of the oxygen zone) which is 4,000,000 tons.

It should also be pointed out that a new class of microorganisms has been found in the depths of open seas and oceans (KRISS and MITZKEVICH, 1957). These microorganisms are also of a filamentous structure, but are provided at one end with a sort of a head, representing an agglomeration, or, bunch of rounded bodies strongly refracting light. These microorganisms do not occur in a free-floating state but develop in their typical form only on particles suspended in sea water, and as such were discovered on the submerged fouling glasses. These microorganisms are unable to propagate in media of organic composition. Apparently, the autotrophic microorganisms play a significant part in the primary production of organic matter not only in the Black Sea but in other basins of normal type as well.

Summary

1. The microbiological studies of the Black Sea showed that a peculiar type of filamentous bacteria is widely spread in the deep water. The concentration of these bacteria in the hydrogen sulphide zone of the Black Sea is considerable, the average microbe biomass per m^3 of water of this zone being 1·5–2 times that in the oxygen zone.

2. In the whole Black Sea basin the biomass of the microbic plankton occupies the first place among the other forms of plankton and nekton.

3. Being autotrophic and utilizing hydrogen sulphide, the filamentous microorganisms are the source of the primary production of organic matter in the Black Sea. The Black Sea is an example of a basin where the role of bacteria in the primary production is superior to that played by plants.

References

Archangelsky, A., & Strachov, N., 1938. "Geologicheskoe stroenie i istorya razvitya Chernogo morya". (Geological structure and the history of the development of the Black Sea). Izdatel. Akad. Nauk SSSR, 226 pp. Moskva-Leningrad.

Kriss, A., 1954. "The role of microorganisms in the biological productivity of the Black Sea". Uspekhi Soviem. Biol., **38**: 86–110.

Kriss, A., 1955. "Microbiological research in the vicinity of the North Pole". Vestnik Akad. Nauk SSSR, 1: 30–40.

Kriss, A., 1956. "Microbiology of the Caspian Sea". Uspekhi Sovrem. Biol., **42**: 175–201.

Kriss, A., & Biriuzova, V., 1955. "The vertical distribution of the microorganisms in the Kuril-Kamchatka hollow of the Pacific Ocean". Dokl. Akad. Nauk SSSR, **100**: 1175–78.

Kriss, A., & Mitzkevich, J., 1957. "A new class of microorganisms inhabiting the depths of the sea and oceans (Krassilnikoviae)". Uspekhi Sovrem. Biol., **44**: 269–80.

Kriss, A., & Rukina, E., 1953. "Purple sulphur bacteria in the hydrogen sulphide zone of the Black Sea". Dokl. Akad. Nauk SSSR, **93**: 1107–10.

Kusmorskaya, A., 1950. "Concerning the zooplankton in the Black Sea". Trudy Azovsko-Chernomorskogo Inst. Morsk. Rybn. Khoz. Okeanogr., **4**: 177–214.

Lebedeva, M., 1953. "An evaluation of the number and biomass of the microorganisms in the Black Sea. (Ecological conformity of their distribution)". Avtoreferat dissertatzii.

Morozova-Vodyanitzkaya, N., 1950. "The number and biomass of the phytoplankton in the Black Sea". Dokl. Akad. Nauk SSSR, **73**: 821–24.

Zenkevitch, L., 1947. "Fauna i biologicheskaja productivnostj morja". (Fauna and biological productivity of the sea.) Izdat. "Sovetskaja Nauka", 588 pp. Moskva.

Relative Significance of the Net Phytoplankton and Nanoplankton in the Waters of Vineyard Sound[1])

By

Charles S. Yentsch and **John H. Ryther**

Woods Hole Oceanographic Institution

I. Introduction

Phytoplankton ecologists divide phytoplankton into two major groups based on cell size. To the portion of the population which will pass through the pores of a fine plankton net the term nanoplankton has been applied (LOHMANN, 1903), while the portion of the population retained by the net is termed net phytoplankton. BIRGE and JUDAY (1922) were probably the first workers to assay quantitatively the biomass of these two proportions. They found that the quantity of net phytoplankton showed pronounced seasonal trends while that of the nanoplankton did not. In making quantitative estimates of the standing crop some workers have claimed that net collections are representative (BURKHOLDER, 1933; HARVEY *et al.*, 1935); however, it is apparent from the work of RILEY (1941), HARVEY (1950), WOOD and DAVIS (1956), and STEEMANN NIELSEN (1938, 1957) that a great majority of phytoplankton in most regions of the oceans pass through the fine net.

In this paper we are comparing chlorophyll, photosynthesis, and cell numbers in the net- and nanoplankton in the waters of Vineyard Sound. Our observations cover the period March to the end of July, 1956. We have attempted to assay the importance of the micro-flagellates in the phytoplankton and wherever possible have compared Vineyard Sound data to values found by other workers in different regions of the oceans.

II. Methods

Surface water samples were collected from Vineyard Sound in volumes of 6–20 l by a plastic bucket and poured through a silk No. 25 plankton net (aperture size: 0·065 mm). Care was taken not to clog the net. This plankton sample was then washed into a known volume of filtered sea water from which equal aliquots of the sample were taken for chlorophyll analysis, photosynthesis measurements, and cell counting. Similar analyses were made on the unfiltered

[1]) Contribution No. 984 from the Woods Hole Oceanographic Institution, Woods Hole, Mass. This was supported by research grants from the National Science Foundation.

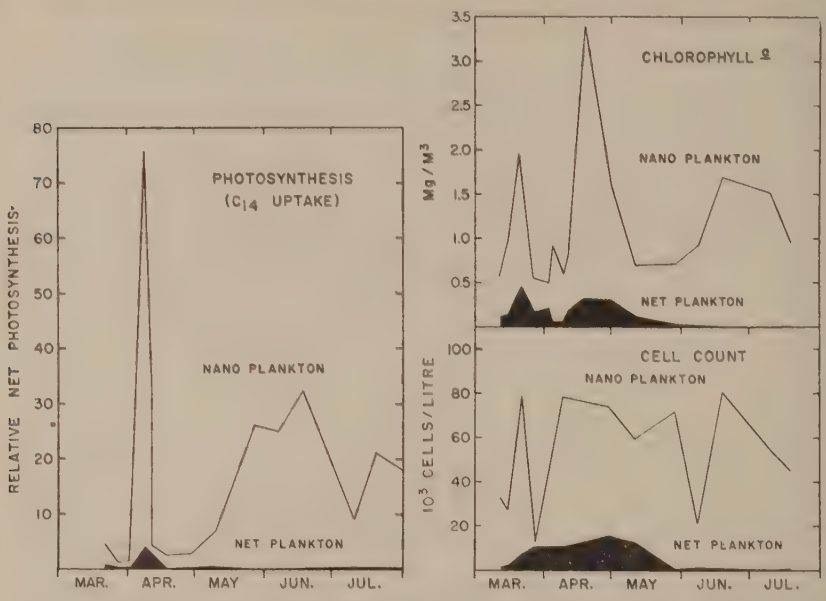

Figure 1. Chlorophyll, photosynthesis, and cell numbers in the net- and nanoplankton in Vineyard Sound, March–July 1956.

raw water collected at the same time. The method of chlorophyll analysis has been described by RICHARDS with THOMPSON (1952) and modified for use with a millipore filter by CREITZ and RICHARDS (1956). Photosynthesis measurements were made by adding 1 ml of $C^{14}O_3''$ to clear and dark glass stoppered bottles to which aliquots of the plankton samples were added. The bottles were suspended in surface waters from a floating dock between the hours of 0900–1500 after which the samples were millipore filtered and the filters counted according to STEEMANN NIELSEN (1952). Photosynthesis corrected for dark uptake is expressed in relative units. Cell counts were made on 1 ml aliquots of the net sample in a Sedgwick-Rafter counting chamber under 100× and 400× magnification. Cell counts were made on a *raw* water sample concentrate obtained by adding 10 ml of neutral formalin to a 500 ml sample and allowing the organisms to settle.

The differences between values of chlorophyll, photosynthesis, and cell number in the *raw* water samples and those obtained from samples collected by the fine net are expressed in this paper as characteristics of the nanoplankton.

III. Results

A. Seasonal sequence

In Figure 1 we have compared net phytoplankton to nanoplankton in terms of the quantity of chlorophyll, cell numbers, and photosynthesis. During the period of observation the net plankton, on the average, comprised 8% of the total chlorophyll, 9% of total cell numbers, and 2% of the photosynthesis. A

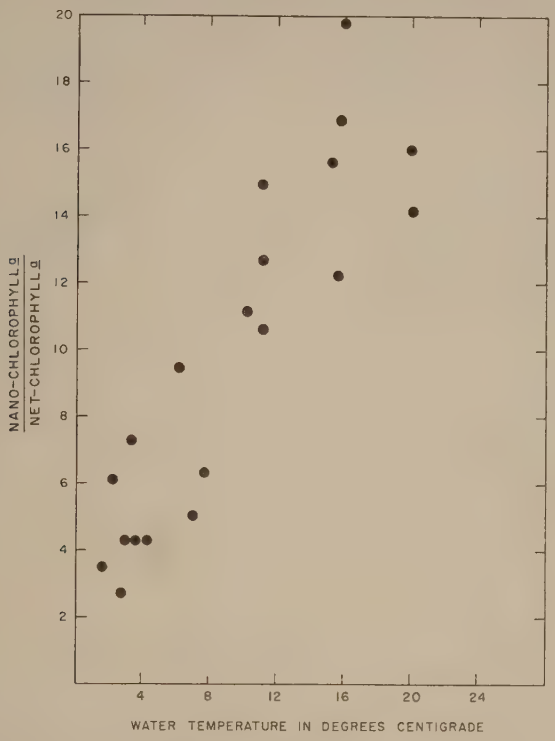

Figure 2. Comparison of mean monthly water temperature on the proportion of net- to nanoplankton chlorophyll.

marked seasonal trend was observed in net plankton chlorophyll, cell number, and photosynthesis. Chlorophyll and cell numbers were highest during March, April, and May while photosynthesis was highest in April. The cell numbers in the nanoplankton exhibited no uniform seasonal trend. However, chlorophyll quantities exhibited three major peaks, one in the middle of March, the other two at the end of April and mid-June. The highest concentration of chlorophyll occurred in April and coincided with the maximum photosynthetic activity. This was also the case in the June peak.

The considerable variability in the biomass of net plankton pointed out by Riley (1941) and others is confirmed by our observations. In Vineyard Sound the ratio between the largest and smallest standing crop of net plankton chlorophyll is 25:1. The same ratio in the nanoplankton chlorophyll is only 6·8:1.

The proportion of the two components of the population, as shown by the ratio of the nanoplankton chlorophyll: net plankton chlorophyll was closely related to the mean monthly water temperature (Fig. 2). During our observations water temperatures covered the range of 2°–21 °C. The catching efficiency of the fine net as shown by the ratio of nano- to net plankton chlorophyll

varied from 3–20. Hence the proportion of nanoplankton in the total population increased seven fold between March and July. The observed correspondence with temperature does not infer that temperature *per se* is responsible for the decreased cell size, which may be influenced by other factors such as light or nutrients.

B. Composition of net- and nanoplankton

The numbers retained by the net when compared with direct counts indicate that even the larger diatoms are not completely collected by fine nets. Species such as *Rhizosolenia styliformis*, *Nitzschia delicatissima*, and *N. seriata* whose over-all cell size is large and whose length greatly exceeds their width could be expected to be retained by chance 50% of the time in the fine net. Likewise, spinous species such as *Chaetoceros* could also have a high retention coefficient. General morphological types such as these were caught at times by the fine net in numbers half as large as the numbers in the settled volume (Fig. 3). Some of the larger genera, *Coscinodiscus*, *Peridinum*, and *Ceratium* were frequently caught with 100% efficiency by the net. Yet the inefficiency of the fine net is shown by the number of different genera whose individuals were never caught by the net, and the large number of genera of which the nets caught less than 10% of the population indicated by the direct count. Examples of these are the genera, *Navicula*, *Thalassiosira*, *Licmophora*, *Gyrosigma*, *Pleurosigma*, *Leptocylindrus*, *Nitzschia closterium*, and the summer form of *Skeletonema*.

C. Chlorophyll content of net- and nanoplankton samples

In all cell counts made on whole water samples marine flagellates such as *Carteria*, or *Dunaliella*, and small dinoflagellates of the genus *Gymnodinium* comprised no more than 2% of the total cell numbers. Therefore, the main constituents of the nanoplankton were diatoms which were not retained by the fine net. If formalin preservation or discrimination difficulties caused large counting errors by omission, the values for cellular chlorophyll in the portion of the population not retained by the net would be unusually large. This does not, however, appear to be the case. In Figure 4 we have compared the cellular

Table 1

Chlorophyll content of different species of phytoplankton

Organisms	Chlorophyll *a* in a single cell (mg)	One mg[1]) count
Greater than 10 microns		
Rhizosolenia alata[2])	$1{\cdot}8 \times 10^{-8}$	56×10^{4}
– *Shrubsolei*[2])	$1{\cdot}6 \times 10^{-8}$	62×10^{4}
Ditylum Brightwellii[2])	$1{\cdot}7 \times 10^{-8}$	59×10^{4}
Skeletonema costatum	$2{\cdot}8 \times 10^{-9}$	35×10^{7}
Phaeodactylum tricornutum	$2{\cdot}0 \times 10^{-10}$	50×10^{8}
Less than 10 microns		
Dunaliella euchlora	$6{\cdot}0 \times 10^{-10}$	16×10^{8}
Carteria sp.	$5{\cdot}8 \times 10^{-10}$	17×10^{8}
Isochrysis galbana	$7{\cdot}5 \times 10^{-11}$	13×10^{9}
Nannochloris atomus	$3{\cdot}0 \times 10^{-11}$	32×10^{9}

[1]) Number necessary to comprise one mg of chlorophyll.

[2]) FLEMING (1940).

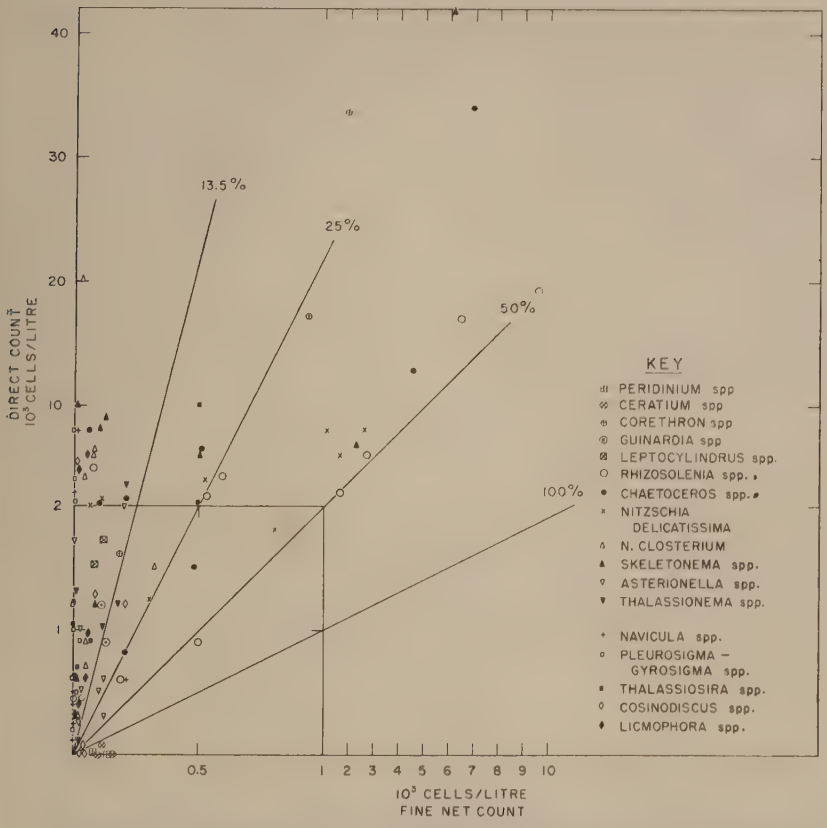

Figure 3. Net retention ratios of major diatom genera sampled in Vineyard Sound, March–July 1956. The two distinct morphological types in the genus *Nitzschia* are separated by species.

chlorophyll content of net plankton and nanoplankton samples. The chlorophyll per cell values for the net samples are representative, almost exclusively, of diatoms because of their larger size. The scatter of the nanoplankton points appears to be no greater than could be expected from analysis of the cell contents of different diatom sizes. Moreover, the points group well around the line which corresponds to $1{\cdot}6 \times 10^{-8}$ mg chlorophyll *a*/cell. This is near the average chlorophyll content of the genus *Rhizosolenia* (see Table 1), which again emphasizes that a major proportion of the chlorophyll in the waters of Vineyard Sound is contained in diatoms, and the nanoplankton is largely diatoms which pass through the fine net. It is perhaps surprising that diatoms within a wide range of cell size have roughly the same amount of chlorophyll. These analyses confirm the visual observation that chloroplasts occupy a proportionately larger fraction of the cell contents of smaller diatoms. Unfortunately little information is available on the cellular chlorophyll content of

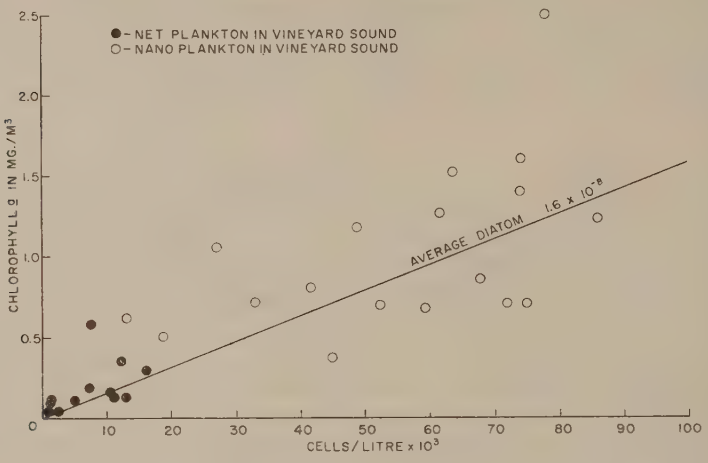

Figure 4. Chlorophyll cell number ratios, Vineyard Sound, March–July 1956.

different species of diatoms. In Table 1 we have compared the cell contents of some diatoms and flagellates. The large differences in cell volumes are apparent when one considers that a diatom such as *Rhizosolenia alata* contains 1000 times more chlorophyll *a* than a cell such as *Nannochloris*. Some of the larger flagellates (*Carteria*, *Dunaliella*) do, however, have chlorophyll contents as large as some of the smaller diatoms.

Discussion

In Table 2 data from various sources compare the percentage of total phytoplankton biomass that can be caught by a net in the various areas sampled. Large percentages of the total phytoplankton biomass may be retained by fine nets in Arctic waters (DIGBY, 1953) as opposed to net retention values given by RILEY (1939) and WOOD and DAVIS (1956) for water of lower latitudes. Observations made in more temperate regions where the temperature range is large (HARVEY, 1950; RILEY, 1941; and this paper) tend to include the extreme net plankton percentages of northern and southern regions. This latitudinal distinction is probably valid for natural marine communities where little influences from land are present such as Vineyard Sound. In an estuary, however, the percentage of phytoplankton retained by a fine net might be much lower due to the prevalence of smaller forms.

Some workers have suggested that the bulk of the organic production in parts of the oceans may be due to the activities of autotrophic flagellates rather than diatoms (ATKINS, 1945; KNIGHT-JONES and WALNE, 1951). Due to the small volume of these cells the numbers necessary to contribute a sizable quantity of chlorophyll are large. For example, KNIGHT-JONES and WALNE (1951) report counts of 50,000 cells of *Chromulina pusilla* per litre in the North Sea. Using the chlorophyll per cell value shown in Table 1 for *Nannochloris*, which is comparable in size to *Chromulina*, the total quantity of chlorophyll

Table 2

The percentage of phytoplankton biomass caught by a No. 25 plankton net in different regions of the oceans

Location	Latitude	% of the total	Author
Scoresby Sound, East Greenland .	70°N	66	Digby (1953)
Off Plymouth, England.....	50°N	10–26	Harvey (1950)
Long Island Sound	41°N	9–56	Riley (1941)
Vineyard Sound.....	41°N	2–47	
New South Wales, Australia	33°S	3–4	Wood and Davis (1956)
Tortugas	24°N	1	Riley (1939)

in the *C. pusilla* populations would be 10^{-3} mg/m^3 or 1/1000 the average chlorophyll content in nearshore marine waters (Ryther and Yentsch, 1958). The counts given by the English workers for *C. pusilla* in rivers and estuaries are much higher and should cause a visible green turbidity which is seldom observed in natural marine conditions. Riley's (1957) data show a range in diatom numbers in the poor waters of the Sargasso Sea of 2,000–58,000 cells/litre. Assuming that the average cellular chlorophyll content of these cells is $1{\cdot}6 \times 10^{-8}$ mg (Table 1), the range of chlorophyll contributed by diatoms alone would be $0{\cdot}03 - 0{\cdot}9$ mg/m^3, which is generally the range observed in this open ocean region. Others have claimed that the importance of the micro-flagellates in the total phytoplankton biomass has been overestimated (Ballantine, 1953). Cushing (1955) states that in most of the oceans diatom numbers are six times higher than flagellates which in terms of chlorophyll would allow the diatom contribution to be 100–1000 times the flagellate contribution. Thus it would appear unlikely that micro-flagellate populations could ever comprise a significant proportion of the bulk of organic production in the oceans.

Summary

Chlorophyll content, photosynthesis, and cell numbers have been compared in the net- and nanoplankton in Vineyard Sound waters. The net portion comprised a small percentage of the total population and exhibited marked seasonal trends while the nanoplankton did not. The composition of the net phytoplankton was exclusively diatoms which because of size or shape were retained by the net. The nanoplankton was comprised almost exclusively of smaller diatoms, or diatoms whose shape was not suitable for net retention.

References

Atkins, W. R. G., 1945. "Autotrophic flagellates as the major constituent of the oceanic phytoplankton". Nature, Lond., **156**: 446.

Ballantine, D., 1953. "Comparison of the different methods of estimating nanoplankton". J. Mar. Biol. Assoc. U. K., **32**: 129–47.

Birge, E. A. and Juday, C., 1922. "The inland lakes of Wisconsin. The plankton. Part I. Its quantity and chemical composition". Wis. Geol. Nat. Hist. Surv., Bull., **64**: 1–222.

Burkholder, P. R., 1933. "A study of the phytoplankton of Frenchman's Bay and Penobscot Bay, Maine". Int. Rev. d. ges. Hydrobiol. Hydrogr., **28**: 262–84.

CREITZ, G. I., & RICHARDS, F. A., 1955. "The estimation and characterization of plankton populations by pigment analysis. III. A note on the use of 'millipore' membrane filters in the estimation of plankton pigments". J. Mar. Res., **14**: 211–16.

CUSHING, D. H., 1955. "Production and pelagic fishery". Fish. Invest. Lond., Ser. 2, **18** (7).

DIGBY, P. S. B., 1953. "Plankton production in Scoresby Sound, East Greenland". J. Animal Ecol., **22**: 289–322.

FLEMING, R. H., 1940. "Composition of plankton and units for reporting populations and production". Proc. 6th Pac. Sci. Congr., **3**: 535–40.

HARVEY, H. W., COOPER, L. H. N., LEBOUR, M. V., & RUSSELL, F. S., 1935. "Plankton production and its control". J. Mar. Biol. Assoc. U.K., **20**: 407–41.

HARVEY, H. W., 1950. "Production of living matter in the sea off Plymouth". J. Mar. Biol. Assoc. U.K., **29**: 97–137.

KNIGHT-JONES, E. W., & WALNE, P. R., 1951. "*Chromulina pusilla* Butcher, a dominant member of the ultraplankton". Nature, Lond., **167**: 4450.

LOHMANN, H. 1903. "Neue Untersuchungen über den Reichtum des Meeres an Plankton und über die Brauchbarkeit der verschiedenen Fangmethoden". Komm. Wissensch. Untersuch. d. Deutschen Meere in Kiel und d. Biologischen Anstalt auf Helgoland, Wiss. Meeresunters., N.F., Abt. Kiel, **7**: 1–86.

RICHARDS, F. A., with THOMPSON, T. G., 1952. "The estimation and characterization of plankton populations by pigment analysis. II. A spectrophotometric method for the estimation of plankton pigments". J. Mar. Res., **11**: 156–72.

RILEY, G. A., 1939. "Plankton studies. II. The western North Atlantic, May–June". J. Mar. Res., **2**: 145–62.

RILEY, G. A., 1941. "Plankton studies. III. Long Island Sound". Bull. Bingham Oceanogr. Coll., **7** (3): 1–93.

RILEY, G. A., 1957. "Phytoplankton of the north central Sargasso Sea". Limnol. Oceanogr., **2**: 252–70.

RYTHER, J. H., & YENTSCH, C. S., 1958. "Primary production of continental shelf waters off New York". Limnol. & Oceanogr., **3**: 327–35.

STEEMANN NIELSEN, E., 1938. "Über die Anwendung von Netzfängen bei quantitativen Phytoplanktonuntersuchungen". J. Cons. int. Explor. Mer, **13**: 197–205.

STEEMANN NIELSEN, E., 1952. "The use of radioactive carbon (C^{14}) for measuring organic production in the sea". J. Cons. int. Explor. Mer, **18**: 117–40.

STEEMANN NIELSEN, E., & AABYE JENSEN, E., 1957. "Primary oceanic production, the autotrophic production of organic matter in the oceans". Galathea Rep., **1**: 50–125.

WOOD, E. J. F., & DAVIS, P. S., 1956. "Importance of smaller phytoplankton elements". Nature, Lond., **177**: 438.

A Standard Terminology and Notation for Fishery Dynamics

By

S. J. Holt
Food and Agriculture Organization of the United Nations, Rome

J. A. Gulland
Fisheries Laboratory, Lowestoft, England

C. Taylor
U.S. Fish and Wildlife Service, Woods Hole, U.S.A.

and

S. Kurita
Tokai Regional Fisheries Research Laboratory, Tokyo

Introduction

In view of the rapid increase in publications dealing with various aspects of fishery dynamics, the need was recognized at the Special Meeting held by the Research and Statistics Committee of the International Commission for the Northwest Atlantic Fisheries (ICNAF) at Biarritz in March 1956, for standardization of the mathematical symbols for the most commonly used quantities. The basis for discussion was a review prepared by GULLAND (1956, 1958); a system of notation was proposed, and provisionally accepted by the Commission at the 1956 Annual Meeting for use in its publications.

The proposals were next communicated to Dr. Susumu KURITA, of the Tokai Regional Fisheries Research Laboratory, who convened a small group of Japanese scientists to consider them. The group, consisting of: Mr. KURITA (Chairman), Mr. Takeyuki DOI, Mr. Syoiti TANAKA, Mr. Shigeichi HAYASHI (Tokai RFRL), Mr. Ichiro YAMANAKA (Japan Sea RFRL, Niigata) and Mr. Nobuhiko HANAMURA (Hokkaido RFRL, Yoichi), reported its discussions in a paper (KURITA, 1957) submitted to the Joint Scientific Meeting of the International Commission for the Northwest Atlantic Fisheries, the International Council for the Exploration of the Sea, and the Food and Agriculture Organization of the United Nations at Lisbon, May/June 1957. Consideration of this document led the meeting to prepare a report on the matter and to recommend: "that this report be brought to the attention of the Japanese committee, who should be invited to forward their comments to a group consisting of Mr. TAYLOR (ICNAF), Mr. GULLAND (ICES) and Mr. HOLT (FAO). Any change

from the Biarritz notation agreed by this group should then be placed before the first convenient meetings of ICNAF and ICES with the strong recommendation that the revised notation should be adopted by all workers in the respective organizations. Meanwhile the group should bring the proposed notation to the attention of workers in areas other than those mentioned above and should take steps to obtain its adoption by other International fishery organizations."

The actions suggested have been taken and the 45th Statutory Meeting of ICES at Bergen 1957, recommended the adoption by its member countries of the notation as finally amended. We believe the result of this exchange of views and ideas is substantial agreement among interested scientists in countries conducting research on the dynamics of fish populations on a notation which, although not free from logical defects, nor conforming wholly with any other commonly used notation, can nevertheless be adopted for the greatest convenience of research workers throughout the world without necessitating complete change in the practices of any one group.

Our recommendations are being made known not only to international fisheries councils and commissions but also to the editors of periodicals publishing papers on fishery dynamics, with the request that they bring the proposals to the attention of their contributors and readers. Just as most journals will accept only contributions written in one of a specified group of languages, it may be that editors will find it possible either to use the standard notation throughout or at least to make it a condition of acceptance of an offered contribution that, if the standard forms are not used, all terms and symbols be precisely defined. This would make it possible to reduce, by omission of such definitions, the texts of papers in which standards are used.

English was the working language of the Biarritz and Lisbon meetings so that symbols we recommended stood for concepts expressed in that language. Work has, however, begun in preparing lists of equivalent terms in other languages. The Japanese group referred to above submitted to the Lisbon meeting a list of Japanese equivalents, and Drs. G. Hempel and D. Sahrhage have recently prepared, in collaboration with Professors A. Bückmann, J. Lundbeck, and A. von Brandt, a list of terms in German. They have kindly agreed that extracts from their list should be used here, and in the following table the standard symbols are therefore accompanied by equivalent terms in three languages. Steps are being taken to have equivalent lists drawn up in other languages used in international publications, particularly French, Russian, and Spanish. Definition of the derived quantities is made without reference to language by expressing their relations with the fundamental quantities by algebraic formulae.

Estimates of quantities may be symbolized by use of lower case type, except for fishing mortality coefficients and number of fish in stock, when ambiguity might be created with effective fishing intensity, and age-group numbers respectively. Alternatively, the common statistical practice of using a circumflex accent to indicate an estimate is recommended.

Lastly, mention should be made of typography and the units in which quantities are expressed. It seems to be preferable to print symbols for quantities in italics, reserving roman type for units of measurement thus: –

$$Y = 8{\cdot}3 \times 10^9 \text{ g}$$

This is becoming common practice. We would draw attention to the article in *Science* (D.R., 1954), which proposes standards for the formation of symbols

Terminology and Notation for Fishery Dynamics

Symbol	English definition	Terminology		
		English	Japanese	German
N	Total number of fish in stock	Stock number	Sigen-bisû	Stückzahl der Fische eines Bestandes
P	Total weight of fish in stock	Stock biomass	Sigen-zyûryô	Gesamtgewicht der Fische (Biomasse)
C	Total number of fish in catch	Catch in number	Gyokaku-bisû	Fang in Stückzahl
Y	Total weight of fish in catch	Catch in weight	Gyokaku-zyûryô	Fang in Gewicht
Z	Instantaneous total mortality coefficient $= -dN/Ndt = F + M$	Total mortality coefficient	Zengensyô-keisû	Exponentieller Koeffizient der Gesamtverluste
F	Instantaneous coefficient of mortality caused by fishing	Fishing mortality coefficient	Gyokaku-keisû	Exponentieller Koeffizient der fischereibedingten Verluste
M	Instantaneous coefficient of mortality by (natural) causes other than fishing	Natural mortality coefficient	Sizensibô-keisû	Exponentieller Koeffizient der natürlichen Verluste
R	Number of fish entering the exploitable phase of a stock in a given period	Number of recruits (Annual) recruitment	Kanyûryô	(Jährlicher) Nachwuchs des befischten Bestandes (Stückzahl)
l	Length of a fish	Fish length	Taityô	Länge
w	Weight of a fish w (stock) $= P/N$ w (catch) $= Y/C$	Fish weight	Taizyû	Gewicht
t	Time, either absolute or in terms of life-span of fish, thus:		Zikan	als Index: Wert eines Parameters zu einer bestimmten Zeit
t_r	Age at which fish are recruited to fishable stock	Age at recruitment	–	Nachwuchsalter, mittleres Alter der Fische eines Bestandes beim Eintritt in den Fangbereich
and				
t_c	Age at which fish are first liable to capture by the fishing gear in use	Age at first capture	–	Mindestfangalter, mittleres Mindestalter der fangbaren Fische
l_c	Length of fish at age t_c	Length (size) at first capture	–	Mindestlänge fangbarer Fische
w_c	Weight of fish at age t_c	Weight at first capture	–	Mindestgewicht fangbarer Fische
l_r	Length of fish at age t_r	Length at recruitment	–	Mittlere Länge der Fische beim Eintritt in den Fangbereich
w_r	Weight of fish at age t_r	Weight at recruitment	–	Mittleres Gewicht der Fische beim Eintritt in den Fangbereich
X	Fishing effort. This symbol should be used only if no ambiguity will arise with statistical notation in this context; otherwise the following notation is to be preferred, and used in any case when distinction is to be made between uncorrected fishing effort statistics, as recorded, and the *effective overall fishing intensity* computed from them	Fishing effort	Gyokaku-doryokuryô	Fischereiaufwand
g	Fishing effort as recorded	Uncorrected fishing effort	–	Fischereiaufwand, Befischungseinheit (ungewogen)
f	Weighted mean fishing effort per unit area, expressed in standard units and calculated with weighting factors equal to the density of fish in each area	Effective overall fishing intensity	–	Gewogene Befischungsintensität (Fischereiaufwand/Gebietseinheit gewogen nach dem Einheitsfang als Ausdruck für die Verteilung der Fische)
S	$exp\ (-Z)$	Fraction surviving (Mean) survival rate	Seizan-ritu	Prozentsatz der Überlebenden
–	$1-S$	Mortality rate	Zengensyô-ritu	Sterblichkeitsrate
E	$(1-S)\ F/Z$	Exploitation rate or Unconditional fishing mortality rate or	Gyokaku-ritu	Fischereibedingte Todeserwartung
	$(1-S)\ F/Z$	Expectation of death by capture		
D	$(1-S)\ M/Z$	Unconditional natural mortality rate or Expectation of death by natural causes	Sizensibô-ritu	Naturbedingte Todeserwartung
q	F/f	Catchability coefficient	–	Einheitsfang, Ertrag je Befischungseinheit
–	Y/f, C/f, Y/g, C/g	Catch per unit effort	–	
Suggested suffixes:				
i or x	Year-class		nem	Jahrgang, Jahresklasse
j or n	Age-group		nenrei	Altersgruppe

for units which might well be adopted by fisheries workers (see appendix), and we would end with the plea that, at least in publications of an international nature, the centimetre/gramme/second system of units should be used whenever possible as the basis for defining derived units, and for expressing results of research.

References

D.R., 1954. "Symbols for units of measurement". Sci. N.Y., **120**: 1078–80.

Gulland, J. A., 1956. "Notations in fish population studies". Contribution 2, Working Party No. 3 (Population Dynamics), ICNAF Spec. Meet. Commit. Res. and Statist., Biarritz, France, March 1956. (Mimeogr.)

Gulland, J. A., 1958. "Notations in fish population studies" (abstract only) *in* "Some problems for biological fishery research and techniques for their solution". Symposium held at Biarritz, France, 1.–10. March 1956. Spec. Publ., ICNAF, 1. (In press.)

Kurita, S., 1957. "A plan for standardisation of terms and notations in population analysis". Conclusions of the Special Committee which met in Tokyo, on 4. December 1956. Paper 6, Joint Scientific Meeting of ICNAF/ICES/FAO, Lisbon, Portugal, May 1957. (Mimeogr.)

Appendix

Proposed rules for construction and use of symbols for units of measurements (adapted from D. R., (1954)).

1. The symbol preferably should consist of two or three letters and never more than four.

2. The symbol preferably should consist of the first two or three letters of the name of the unit.

3. Preferably there should be only one symbol for a particular unit.

4. Periods (full points), should be omitted from symbols (with the exception of "in." for "inch").

5. The symbol for a combining form denoting a multiple or sub-multiple should be a single letter, thus "k" for "kilo-".

6. Symbol for the unit should be set in roman type.

7. Abbreviated unit symbols should be used only when they are preceded by a numerical value, a symbol for the quantity, or when they appear in headings of tables or crowded text, in which cases the unit symbol is enclosed in parentheses.

8. Standard signs should be used to indicate all mathematical operations with unit symbols, thus division should be indicated by a solidus, a negative exponent or shown in the ordinary fractional form, but the symbol "p" for "per" should not be used, thus: "C/F" or "C.f^{-1}" are preferable to "C.p.u.e." or "Cpf" for "catch per unit effort".

Hyphens should only be used to separate parts of a single unit symbol and not to indicate multiplication, thus: "ST ton hours" is preferable to "S/T ton-hours" for "the product of tonnage and hours fished by steam trawlers".

Biogeographical Fishery Complexes of the Atlantic and Pacific Oceans and their Comparison

By

T. S. Rass

Institute of Oceanology, Academy of Sciences of the USSR, Moscow

Introduction

The total world catch of fish and shellfish estimated in the pre-war year of 1936 at 18·2 million tons (RASS, 1948), has greatly increased during the post-war period. In 1953 it reached 24·8, in 1955 27·9, and in 1956 29·3 million tons (FAO Yearbook, 1957). About 70% of this catch is taken in the temperate zone of the Northern Hemisphere. Not taking into account the world catch in inland waters (estimated for 1953–1955 at 2·6–3·0 million tons, or about 10–11%), the Northern Hemisphere yields more than three quarters (about 76%) of the world sea catch corresponding to 16·8 million tons in 1953 (FAO Yearbook, 1957) including 15·3 million tons of fish.

MURRAY and HJORT (1912) observed that there are some biogeographical elements in the compositions of catches in different regions of the ocean. According to climatic regions of the world ocean there may be distinguished different sets of the main foodfish species, which may be called biogeographical fishery complexes (RASS, 1950). Each complex accounts for the most characteristic bulk of the catch in a given climatic region. At present we distinguish (Fig. 1) one Arctic, two north boreal (Atlantic and Pacific), four south boreal (western and eastern Atlantic; western and eastern Pacific), three tropical (Atlantic, Pacific, and Indian), three antiboreal or notal complexes. The contribution of the northern complexes to the fish catch may be roughly estimated at 0·1 million tons for the Arctic[1]), about 8·8 million tons for the north boreal and about 7·9 million tons for the south boreal regions.

The fish in each complex comprises plankton feeders, benthos feeders and predators, and strictly marine and anadromous species. In the different zones these links are represented by different forms.

[1]) The FAO Yearbook of 1956 gives for the catch in the Arctic the figure of 1·1–1·2 million tons, evidently including the whole Barents Sea into the Arctic zone (see map, FAO Fisheries Bulletin, **5** (3 4), 1952). This of course is incorrect. No separate figures for the Arctic at all are given in the Yearbook of 1957.

The Arctic Complex

The Arctic fish complex characteristic for the waters of Northern Greenland and Spitsbergen, the northern and eastern Barents Sea, the White Sea, and the Arctic seas of Northern Asia and North America is made as follows: 1. Plankton eaters — *Clupea pallasi maris = albi* and *C. pallasi suworowi* (Clupeidae), *Boreogadus saida* (Gadidae), *Mallotus villosus* (Osmeridae). 2. Benthos eaters — *Eleginus navaga*, *Microgadus tomcod* (Gadidae), *Liopsetta glacialis* (Pleuronectidae). 3. Predators — *Myoxocephalus quadricornis*. 4. Semi-anadromous and anadromous predators and plankton eaters — *Osmerus eperlanus dentex*, *Salvelinus alpinus*, *Coregonus* spp. (*C. lavaretus pidschian*, *C. autumnalis*, *C. sardinella*, *C. muksun*, *C. peled*, *C. nasus*).

The North Boreal Complex

Adjacent to the Arctic complex are the north boreal Atlantic and Pacific complexes. Their compositions are very similar (Berg, 1947) comprising northern clupeids, gadoids, flatfish, salmonids, and scorpaenids. In the Atlantic and in the Pacific these complexes contain a number of related species (Table 1): — Atlantic and Pacific herring (*Clupea harengus — C. pallasi*), cod (*Gadus morrhua — G. macrocephalus*), many flatfish (*Platessa platessa — P. quadrituberculata; Limanda limanda — L. aspera; Hippoglossoides platessoides — H. dubius, H. elassodon; Hippoglossus hippoglossus — H. stenolepis*), redfish (*Sebastes marinus — S. flammeus*) and related genera; salmonids (*Salmo — Oncorhynchus*), and redfish or rockcod (*Sebastes — Sebastodes, Sebastolobus*).

The total catch in the north boreal zone of both oceans amounts to about 8·8 million tons. To this total more than three quarters are contributed by the Atlantic and about one quarter by the Pacific (Table 1). Cod and herring which are represented in both oceans by related species give from 4 to 35 times greater catches in the Atlantic than in the Pacific. The same applies to the Atlantic *Sebastes* as compared to the Pacific *Sebastes* (*Sebastodes*) and *Sebastolobus*.

The catches of flatfish are in general similar in size; the catch of the Atlantic *Platessa platessa* is, however, greater than that of the Pacific *P. quadrituberculata*, whereas the catches of the Pacific species *Hippoglossus* and *Limanda* are greater than those of related Atlantic species. The Atlantic salmon (*Salmo*) are caught in practically negligible quantities, whereas the catches of Pacific salmon (*Oncorhynchus*) are very high. An important part of the catch in the Pacific is composed by Mintai or Pacific pollack (*Theragra*) and greenling (*Pleurogrammus*), which do not occur in the Atlantic. These differences may be attributed to different causes (see, e.g. Moiseev, 1956a).

The Atlantic herring and cod differ greatly from their Pacific counterparts in the biology of spawning and development. Both Atlantic species are strictly boreal: they develop under fairly stable temperature conditions (2°–9°C) in contrast to the Pacific species, which develop under entirely different conditions. The eggs of the Pacific herring are deposited very near the shore-line on seaweeds at a depth of 0 to 5 m, where they are greatly affected by changes in temperature, from several degrees below zero to +15°C (Ambroz, 1931). This accounts for the very strong fluctuations occasionally observed in the abundance of Pacific herring, which are caused by changes in the ice conditions in the spawning areas.

Table 1

North Boreal biogeographical fishery complexes (1953 catches, in 1,000 tons)

Main sources: Bull. Stat. ICES, 1955; Anon, 1957; Stat. Bull. ICNAF, 1955; FAO Yearbook, 1957.

North Boreal Zone on the whole	Atlantic complex	Pacific complex
Total 8800	 6800	 2000
Clupeidae 2938	 2337	 601
	Clupea harengus 2337	*Clupea pallasi* 601
Salmonidae 468	 8	 460
	Salmo spp. (*S. salar*, *S. trutta*) 8	*Oncorhynchus gorbuscha* .. 235
		O. keta 99
		O. nerca 62
		Others (*O. tschawytscha*, *O. kisutch*, *O. masu*) 64
Gadidae 3397	 3050	 347
	Gadus morrhua 2170	*Gadus macrocephalus* 60
	Melanogrammus aeglefinus 412	*Theragra chalcogramma* .. 280
	Pollachius virens 233	*Eleginus gracilis* 7
	Others 235	
Scorpaenidae 350	 310	 40
	Sebastes spp. (*S. marinus*, *S. mentella*) 310	*Sebastes* (or *Sebastodes*?) spp. (*S. flammeus* and others) 21
		Sebastolobus macrochir ... 19
Hexagrammidae ... 173	.....	 173
		Pleurogrammus azonus ... 166
		Others (*Pl. monopterygius*, *Hexagrammus* spp.) 7
Pleuronectidae 442	 222	 220
	Hippoglossus hippoglossus 15	*Hippoglossus stenolepis* 33
	Platessa platessa 106	
	Pleuronectidae spp.:	Pleuronectidae spp.:
	Western coast (*Limanda ferruginea*, *Hippoglossoides platessoides*, *Pseudopleuronectes americanus*, *Glyptocephalus cynoglossus*) 60	Western coast (*Limanda aspera*, *L. punctatissima*, *Hippoglossoides dubius*, *H. elassodon*, *Pseudopleuronectes herzensteini*, *Cleisthenes herzensteini*, *Pleuronectes stellatus*, *Lepidopsetta bilineata*, *Platessa quadrituberculata*, *Atheresthes evermanni*) ... 176
	Eastern coast (*Limanda limanda*, *Hippoglossoides platessoides*, *Pleuronectes flesus*, *Microstomus microcephalus*) 40	Eastern coast (*Pleuronectes stellatus*, *Eopsetta jordani*, *Atheresthes stomias*, *Microstomus pacificus*, *Glyptocephalus zachirus*) .. 11
Others (fish and shellfish) 1032	 873	 159

Note:
Some of the figures in Tables 1–3 have been rounded off.

Unlike the Atlantic cod (*Gadus morrhua*) the Pacific species (*G. macrocephalus*) has demersal adhesive eggs. Consequently its spawning and development depends greatly on the depth and the types of bottom. A comparison of the numbers of the Atlantic and Pacific cod eggs and larvae taken on the spawning grounds shows a much greater abundance of the former. The quantities of cod eggs and larvae taken off the Lofoten Islands amount to 6000–13,000 and 1600–3000 beneath 1 m^2 of sea surface respectively (Wiborg, 1954); the number of cod larvae off Kamchatka is only 20–30 beneath 1 m^2 of sea surface (Mukhacheva and Zvyagina, in press). On the other hand, the Pacific pollack (*Theragra chalcogramma*) which has pelagic eggs, is much more abundant than the Pacific cod, giving up to 18,000 29,600 eggs and 1400–1560 larvae beneath 1 m^2 of sea surface (Gorbunova, 1954). At present (1953–1956) the catch of Pacific pollack amounts to 0·3–0·5 million tons but by analogy with the Atlantic cod this catch may probably be increased considerably.

Similarly to the Pacific cod, several Pacific species of flatfishes (*Liopsetta obscura*, *Pseudopleuronectes yokohamae*, *Lepidopsetta bilineata*, *L. mochigarei*) have demersal adhesive eggs (Pertseva-Ostroumova, 1953; 1955). Most flatfishes including the most abundant species *Limanda aspera*, *Hippoglossoides elassodon*, *H. dubius*, *H. robustus*, *Pleuronectes stellatus*, and *Platessa quadrituberculata* have, however, pelagic eggs and their spawning conditions are similar to those of their counterparts in the Atlantic Ocean.

The catches of Scorpaenidae in both oceans are not quite comparable as their fishery in the Pacific has not yet been sufficiently developed. Both Atlantic and Pacific species are viviparous.

An essential biological difference exists between the Atlantic salmon (*Salmo salar*, *S. trutta*) and the Pacific salmon (*Oncorhynchus gorbuscha*, *O. keta*, *O. nerka*, *O. tschawytscha*). While both Pacific and Atlantic salmon deposit their eggs in rivers and streams, the Pacific salmon prefer the places characterized by the seepage of underground water, where their eggs are better protected against freezing during severe winters.

Greenling or Atkafish (*Pleurogrammus azonus*, *P. monopterygius*, *Hexagrammus lagocephalus*, and others) spawn under quite peculiar conditions. They deposit their eggs late in summer attaching them to stones and rocks in the coastal shallow water areas with strong currents. On hatching, the larvae are dispersed by currents over vast areas, up to 200 miles from the coasts. Throughout the winter and until March-April the larvae live pelagically in the surface layer of the open sea. In the Atlantic Ocean no species with a similar winter oceanic larval stage seem to exist.

The South Boreal Complexes

The total catch in the south boreal zone of the Atlantic and the Pacific amounted in 1953 to 7·9 million tons. Contrary to the north boreal zone, the catch in this zone is lower in the Atlantic (3·2) than in the Pacific (4·7). The species in the south boreal geographical fishery complexes is quite unlike that of the north boreal complexes.

A very characteristic feature is a considerable increase in the number of pelagic species, plankton feeders, and predators represented by clupeids,

anchovies, skippers or sauries, carangids, and scombrids. Clupeids are represented by pilchards or sardines and menhadens (*Sardina*, *Sardinops*, *Brevoortia*), brackish-water sprats and *Clupeonella*, and the anadromous alewife and shad or alose (*Sprattus*, *Clupeonella*, *Pomolobus*, *Alosa*); anchovies by one or two species (*Engraulis*, *Anchoa*); skippers and saury by *Belone*, *Scombresox*, *Cololabis*; while carangids are represented by horse mackerel, yellowtail, and some others (*Trachurus*, *Caranx*, *Seriola*). The north boreal flatfish are substituted mainly by *Rhombus* spp. and *Paralichthys* spp. The gadids are represented only by whiting, hake, and rockling (*Odontogadus merlangus*, *Merluccius* spp., *Urophycis*, *Motella*, and some others). In the south boreal zone the biological place of the Gadidae seems to be taken by croakers (Sciaenidae) which are particularly abundant in the Pacific.

In the Atlantic (Table 2) there is an essential difference between the composition of the catches taken in the western and the eastern parts.

Off the western coast the most important species are menhaden and mackerel which constitute about three-quarters of the total catch; they are followed by hake, anadromous clupeids, and croakers. In the east the most important species are pilchard, anchovy, horse mackerel, mackerel, whiting, and hake; then come sprat, anadromous clupeids, and turbot. It may be noted that, as distinct from the north boreal complexes, here pelagic fishes are of much greater importance both in the west and in the east.

In the south boreal zone the catch composition in the Pacific (Table 3) differs from that in the Atlantic to a much greater extent than in the north boreal zone. This is particularly true for the more northern species. The clupeids, scombrids, and sciaenids are represented by distinct Pacific genera — *Sardinops*, *Pneumatophorus*, *Pseudosciaena*, *Nibea*. The saury (*Cololabis*) is purely Pacific. The south boreal Pacific anchovies, on the contrary, belong to the genus *Engraulis* which is of great commercial importance in the eastern Atlantic, the carangids belong to the genus *Trachurus*, common for both oceans.

The sardine (*Sardinops*) and the mackerel (*Pneumatophorus*) play the same part in the Pacific as the pilchard (*Sardina*) and the Atlantic mackerel (*Scomber*) in the Atlantic; the two former genera penetrated into the Atlantic basin along the southern coast of Asia and Africa.

The most important differences that distinguish the south boreal complexes of the Pacific from those of the Atlantic are the abundance of croakers, yielding in the West Pacific about 600 thousand tons yearly; the temporary abundance of sardine whose present catch amounts to about 360 thousand tons but rises occasionally to enormous quantities (as for instance in 1936–37, when it exceeded 2500 thousand tons in the west and 700 in the east); the abundance of saury, whose yield has greatly increased in recent years (250 thousand tons in 1953, about 500 thousand tons in 1955). The catches of anchovy, mackerel, and horse mackerel are also much higher in the Pacific than in the Atlantic. However, the catches of Gadidae (*Merluccius productus*) and anadromous clupeids are very poor. On the whole the catch in the Pacific south boreal zone is higher than in the same zone of the Atlantic and exceeds the catch of the north boreal zone, thus contrasting with the situation observed in the Atlantic Ocean (Fig. 1).

The reason seems to lie in a much wider pelagic area in the Pacific as compared to the Atlantic and, consequently, greater abundance of the pelagic fish in warm waters.

Table 2

South Boreal Atlantic biogeographical fishery complexes (1953 catches, in 1,000 tons)

Main sources: Bull. Stat. ICES, 1955; Anon, 1957; FAO Yearbook, 1957.

South Boreal Atlantic Zone on the whole		Western Atlantic (American)		Eastern Atlantic (European)	
Total	3200		1300		1900
Clupeidae	1520		820		710
		Brevoortia spp.	769	*Sardina pilchardus*	390
		Pomolobus spp. (*P. pseudoharengus, P. aestivalis*)	35	*Clupeonella* spp. (*C. delicatula, C. engrauliformis*)	212
		Alosa sapidissima	5	*Sprattus sprattus*	52
		Others	1	*Alosa* spp. (*A. alosa, A. fallax, A. kessleri, A. caspia, A. brashnikovi*)	50
				Others	6
Engraulidae	157		7		150
		Anchoa spp. (*A. epsetus, A. mitchilli*)	7	*Engraulis encrasicholus*	150
Gadidae	295		50		245
		Merluccius bilinearis	41	*Merluccius merluccius*	133
		Urophycis spp. (*U. tenuis, U. chuss*)	6	*Odontogadus merlangus*	105
		Others	3	Others	7
Bothidae	30		5		25
		Paralichthys dentatus	3	*Rhombus* spp. (*R. maximus, R. laevis, R. maeoticus*)	12
		Others	2	*Lepidorhombus whiff*	12
				Others	1
Sciaenidae	25		20		5
		Micropogon undulatus	3	*Sciaena aquila* and others	5
		Cynoscion spp. (*C. regalis, C. nebulosus*)	6		
		Leiostomus xanthurus	5		
		Others	6		
Scombridae	145		15		130
		Scomber scombrus	15	*Scomber scombrus*	120
				Pneumatophorus japonicus	10
Carangidae	141		1		140
		Caranxhippos, C. crysos, Seriola zonata, S. dumerili, Ocyurus chrysurus, Decapterus punctatus		*Trachurus trachurus*	138
				Seriola dumerili, Lichia glauca	2
Belonidae, Scomberesocidae	9				9
				Belone belone	8
				Scombresox saurus	1
Others	878		392		486

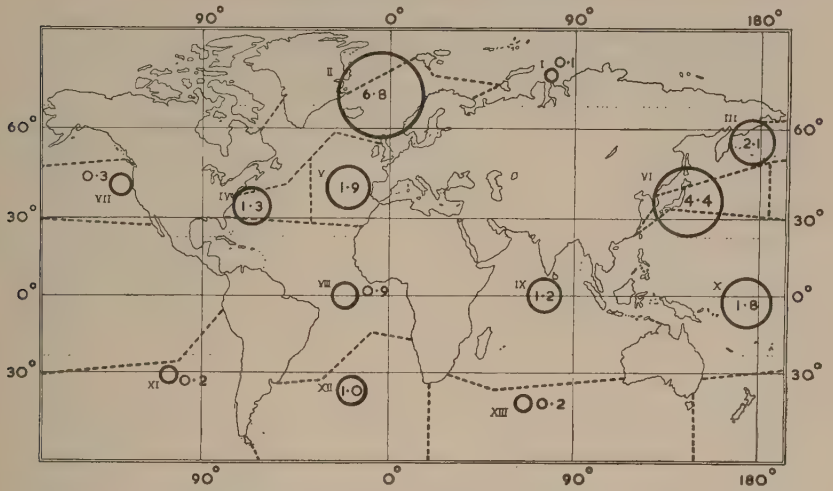

Figure 1. Areas and catches of the biogeographical fish complexes. I: Arctic; – II: North boreal Atlantic; – III: North boreal Pacific; – IV and V: South boreal Atlantic; – VI and VII: South boreal Pacific; – VIII–X: Tropical; – XI–XIII: Notal.

Tropical Complexes

Further to the south there are the tropical complexes. Their specific compositions in the Atlantic, Indian, and Pacific Oceans are again nearer to each other than in the boreal area. Here the clupeids are represented by marine brackish-water and anadromous species (*Sardinella*, *Etrumeus*, *Hilsa*, *Ilisha*); anchovies by a great number of species (*Stolephorus*, *Coilia*, *Scutengraulis*, *Cetengraulis*, *Anchoviella*, southern species of *Anchoa*, etc.).

A characteristic feature of the coastal zone is the occurrence of the milkfish (*Chanos chanos*), saurids (Synodidae-*Saurida* spp.), hairtails (*Trichiurus* spp.) and some others, whereas the oceanic pelagic area is characterized by the occurrence of flying fish (Exocoetidae), tunas (*Thunnus*, *Neothunnus*, *Germo*, *Katsuwonus*, *Euthynnus*, *Parathunnus*), swordfish (*Xiphias*), and marlins (*Makaira* spp. and allied), king mackerels and allied (*Scomberomorus* spp. and others), dolphins or dorads (*Coryphaena*) and others.

Discussion

The practical importance and the biology of the principal components of the fishery complexes can be related to the oceanographical features (taken from Zenkevitch, 1951; Shokalskiy, 1917; Marine Atlas 1953) as shown by Figure 2.

The Atlantic Ocean is much smaller than the Pacific (106·5 as compared to 179·7 million km^2). At the same time the area occupied by its continental shelf is 1·5 times greater (14·2 as compared to 10·2 million km^2).

Table 3

South Boreal Pacific biogeographical fishery complexes (1953 catches, in 1,000 tons)

Main sources: Fah Hou-Ning, 1955; Kim Min-Sou, 1951; Moiseev, 1956b; Anon, 1957; FAO Yearbook, 1957.

South Boreal Pacific Zone on the whole		Western Pacific (Asiatic)		Eastern Pacific (American)	
Total	ca. 4700		4400		300
Clupeidae	370		364		6
		Sardinops sagax melanosticta	344	*Sardinops sagax caerulea*	5
		Others	20	*Alosa sapidissima*	1
Engraulidae	300		260		40
		Engraulis japonicus	255	*Engraulis mordax*	40
		Others	5		
Gadidae	0·1				0·1
				Merluccius productus	0·1
Bothidae and southern Pleuronectidae	112		102		10
		Paralichthys olivaceus.	12	*Paralichthys* spp. (*P. californicus* and others), *Citharichthys sordidus*, *Parophrys vetulus* and others	10
		Pleuronichthys cornutus, *Cleisthenes herzensteini*, *Microstomus achne* and others	90		
Sciaenidae	604		600		4
		Pseudosciaena spp. (*P. manchurica*, *P. polyactis*)	543	*Cynoscion nobilis*, *Genyonemus lineatus*	4
		Nibea spp. (*N. argentata*, *N. nibe*)	32		
		Others (*Miichthys miiuy*, *Collichthys* spp.)	25		
Scombridae	320		315		5
		Pneumatophorus spp. (*P. japonicus*, *P. tapeinocephalus*)	315	*Pneumatophorus diego*	4
				Others	1
Carangidae	335		305		30
		Trachurus japonicus	250	*Trachurus symmetricus*	25
		Seriola spp. and others	55	*Seriola dorsalis* and others	5
Scombresocidae	260		260		
		Cololabis saira	260	*Cololabis saira*	
Mugilidae	16		15		1
		Mugil spp. (*M. cephalus*, *M. so-iuy*)	15	*Mugil cephalus*	1
Sparidae	65		65		
		Pagrosomus major, *Taius tumifrons*, *Evynnis japonicus*, *Sparus swinhonis*	65		
Elasmobranchii (Selachii, Holocephali)	140		136		4
		Selachii	110	Selachii, Batoidei	3
		Trygonidae, Rajidae	26	*Hydrolagus colliei*	1
Others (fish and shellfish)	2162		1962		200

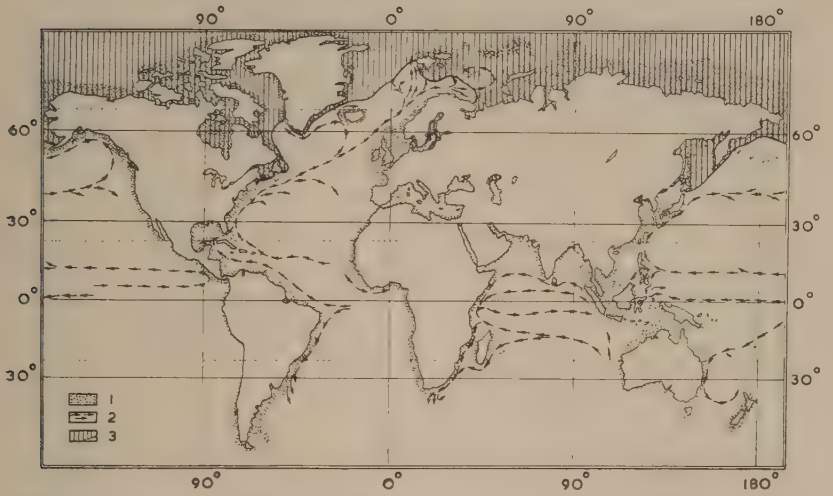

Figure 2. Comparison of geographical characteristics of the Atlantic and Pacific Oceans. (1) Continental shelf; (2) Major warm currents; (3) Winter ice cover.

The main warm currents governing the climates of the oceans are entirely different in the North Atlantic and in the North Pacific. In the Atlantic Ocean the streams of the warm North Atlantic Current, the Gulf Stream, move north-eastwards branching out northward of 45°N into the Irminger, Norwegian, Spitsbergen, and North Cape Currents. In the Pacific Ocean the warm North Pacific Current, the Kuroshio, flows mainly to the east and only the Alaska Current extends northward of 45°N.

Both oceans differ greatly in ice conditions (Fig. 2). In winter (February) the waters of the Atlantic Ocean northward of 60°N (including the Norwegian Sea and the south-western part of the Barents Sea) are mostly free from ice. On the contrary, the Pacific seas northward of 60°N are in winter entirely covered with ice.

The climates of the North Atlantic and North Pacific differ considerably, which may be illustrated by a comparison of the mean temperature range in corresponding latitudes. In the Atlantic Ocean at the 0° and 30° meridians the temperature of the upper layer at 60°N varies yearly only within the range of 4·5°C–5·0°C (from 5–7°C to 10–12°C) whereas in the Pacific Ocean, within the Bering Sea, at the 180° meridian it varies by 10° (from −1·7°C to 8°C). At 40°N the temperature in the Atlantic Ocean is also higher and its annual range of fluctuations is 1·5 times narrower than in the Pacific: here the annual range of fluctuation is 7°C in the Atlantic and 10°C in the Pacific. In these latitudes the waters of the Atlantic Ocean are much warmer than those of the Pacific in winter and slightly warmer in summer. At 30°N this difference is less and southward of 30°N the Atlantic Ocean appears to be colder than the Pacific.

Thus the climate of the North Atlantic appears to be warmer and milder than the climate of the North Pacific; however, southward of 25°N the waters of the Atlantic are cooler than those of the Pacific. The meridional changes in

temperature are less significant in the Atlantic than in the Pacific. Owing to the fact that in the North Pacific Eurasia and America come so close together the climate in this part of the ocean is more continental than the temperate climate of the Atlantic Ocean; only the hydrological characteristics of the lower Arctic White Sea are similar to the conditions of the North Pacific. Here the surface temperatures vary annually from −1·4°C in winter (under the ice cover) to +14·7° in summer (Derjugin, 1933; Zenkevitch, 1947). A comparison of the distribution, biology, and relative abundance of the vicarious north boreal species of Atlantic and Pacific foodfishes suggests that these species, typically boreal in the Atlantic, possess in the Pacific some features of adaptation to the life under lower Arctic conditions. In the Atlantic Ocean the areas of distribution of the cod, herring, and plaice generally do not extend beyond the limits of seas which are not covered with ice, penetrating into ice-covered seas by their marginal parts only. In the seas of the Pacific, on the contrary, the areas of distribution of these fishes are, in general, confined to freezing seas only partly extending into waters without the ice cover.

Some characteristics of adaptation to the conditions of the lower Arctic, analogous to those observed in the White Sea, are reflected in the spawning and development of the Pacific herring, cod and, to some extent, in flatfish and salmon.

The spawning of the Pacific herring in the coastal zone may be considered as an adaptation to the utilization of the earliest thawing parts of the freezing seas. The fact that the Pacific cod and several early spring spawning flatfish have demersal eggs also seems to be an adaptation to the utilization of the bottom layer for their breeding, for in the seas which are covered with ice in winter the bottom layer is free from freshening in spring and is very well aerated.

These features of breeding and development seem to be adaptations to conditions of existence which are more severe than they are in the Atlantic Ocean; they have probably developed during the period when the North Pacific was colder than it is now. The Pacific herring and cod may have originated from ancestral Atlantic species (Svetovidov, 1949, 1952) which spread via the Polar basin along the Sibirian and Arctic American coastline during one of the warmer interglacial periods (Berg, 1947; Andriashev, 1944).

The breeding and the development of the Pacific salmon, *Oncorhynchus*, also reflects an adaptation to harder conditions than is the case with the Atlantic salmon. But here we have to do with specific conditions in the Pacific Ocean — the seepage of ground-water on to the spawning grounds.

In contrast with the herring and cod, the flatfish seem to have spread from the Pacific to the Atlantic (Norman, 1934), the extension having taken place in the North, along the American mainland. There are two points of evidence in support of this, a poorer fauna of the Atlantic flatfish as compared to that of the Pacific and the fact that it is off the western coasts of the Atlantic that we find among the flatfish the same characteristic species related to the flatfish of the Pacific, e. g., the winter flounder, *Pseudopleuronectes americanus*, which has demersal eggs. The breeding of other flatfish, those with pelagic eggs, common to both oceans, takes place either late in spring and in summer (*Platessa*, *Hippoglossoides*, *Limanda*) or early in winter (*Hippoglossus*, *Liopsetta glacialis*).

The comparison of the biogeographical fishery complexes in the Atlantic and in the Pacific suggests the possibility of filling in the missing links into the complexes. For the north boreal zone the missing link in the Atlantic Ocean

seems to be the Pacific greenlings (*Pleurogrammus*, *Hexagrammus*). For the south boreal zone, the Asiatic croakers (*Pseudosciaena*, *Nibea*) in the coastal area and the Pacific saury (*Cololabis saira*) in the oceanic area. A characteristic feature of the Pacific greenlings and saury is the wider utilization of the open oceanic pelagic waters for spawning and development than is the case with related fish species of the Atlantic Ocean.

Summary

1. About 70% of the world catch of fish and shellfish are taken in the temperate and cold waters of the Northern Hemisphere. This catch comprises three different groups of the main foodfish species, the Arctic, north boreal, and south boreal biogeographical fish complexes. There are also the tropical complexes in the tropical zone and antiboreal or notal complexes in the Southern Hemisphere.

2. The north boreal complex makes a major contribution to the total catch in the Atlantic Ocean, and this contribution is much higher than the corresponding catch in the Pacific Ocean. But the south boreal complexes prevail in the catches in the latter area and the contribution of the south boreal complexes to the catch is much higher in the Pacific than in the Atlantic.

3. Each complex contains plankton feeders, benthos feeders, and predators. The bulk of the Arctic complex is formed by the following species: plankton eaters — herring of the White Sea, Petchora Sea and Laptev Sea, capelin and Polar cod; benthos eaters — navaga, tomcod and Arctic flounder; predators — sea-scorpion; semi-anadromous plankton eaters and predators — smelt, char, and many species of whitefish. The bulk of the north boreal complex is formed by herring, gadoids (cod, haddock, and saithe in the Atlantic and Pacific cod and Alaska pollack in the Pacific), redfish, flatfish, salmon, and greenling (last-named only in the Pacific). The major part of the south boreal complexes is formed by pilchard, menhaden, sprat, anchovy, Pacific saury, mackerel, horse mackerel, hake, whiting, and sciaenids (which fill seemingly the biological place of the gadoids in southern waters). The bulk of the tropical complexes is formed by tuna, bonito, king mackerel, dolphin, flying fish, and some others in the pelagic waters, and tropical clupeids, anchovies, scombrids, saurids, milkfish, hairtails, seabreams, seabasses, and others in the shelf waters.

4. Herring and cod which prevail in the north boreal complex in the Atlantic Ocean make a considerably lesser contribution to the catches in the Pacific Ocean. The Pacific herring and cod do not occur outside the waters of the continental shelf and their breeding biology differs from the breeding biology of the Atlantic related species by adaptations to the more rough winter conditions. On the other hand, such north boreal Pacific species as Alaska pollack, greenling, and Pacific salmon whose life cycle is connected with the pelagic area are very numerous in the Pacific Ocean. The strictly pelagic south boreal saury and tropical tuna of the Pacific Ocean are much more abundant in the Pacific than in the Atlantic.

5. These differences may be accounted for by the differences in the past history and the recent climatic conditions of the Atlantic and Pacific Oceans. The former is characterized by the more temperate climate, smaller ice-covered area, greater area of the continental shelf, while the characteristic feature of

the latter is the great oceanic pelagic area and the more continental climate in the northern part. Consequently the northern ichthyofauna in the Pacific Ocean show the special adaptations for rough winter conditions, while the pelagic ichthyofauna (or that which is connected with the pelagic waters) is much more developed in the Pacific Ocean.

Some important fish species of the North Pacific are missing in the North Atlantic; the greenling from the north boreal complex and the saury from the south boreal complex may be used perhaps to enrich the foodfish fauna of the Atlantic Ocean.

References

Ambroz, A. I., 1931. "The herring (*Clupea harengus pallasi* C.V.) of Peter the Great Bay". Bull. Pacif. sci. Inst. Fish., **6**: 1–313. (In Russian, English summary.)

Andriashev, A. P., 1944. "Interrupted distribution of the marine fauna in the Northern Hemisphere". Priroda, 1944 (1): 44–52. (In Russian.)

Anon., 1957. "Specific composition and distribution of catches of fish and shellfish in the USSR". Rybn. Khoz., (Fishery), 1957 (8): 93–96. (In Russian.)

Berg, L. S., 1947. "On the amphiboreal distribution of marine fauna in the Northern Hemisphere". In: Berg's "Climate and Life", 2nd ed., Moscow, 116–27. (In Russian.)

Bulletin Statistique des Pêches Maritimes, Cons. int. Expl. Mer, 1955, **38**: pour l'année 1953.

Deryugin, K. M., 1923. "On the hydrology of the White Sea". Notes on Hydrography. (Zapiski po hydrografii, Leningrad), 47: 37–80. (In Russian.)

Fah Hou-Ning, 1955. "Chinese fishery". Inst. Mar. Biol. Acad. Sci. China, Biol. Bull., 9. (In Chinese.)

FAO Fisheries Bulletin, 1952, **5**: 136–37.

Gorbunova, N. N., 1955. "Spawning and development of the mintai (Alaska pollack, *Theragra chalcogramma* (Pallas)". Trans. Inst. Okeanol. USSR, **11**: 132–95. (In Russian.)

Kim Min Sou, 1957. "Some data on the Far-Eastern mackerel and mintai (Alaska pollack)". Moscow, 20 pp. (In Russian.)

Moiseev, P. A., 1956a. "Fluctuations in the commercial fish populations of the northwestern Pacific in relation to environmental and other factors". Pap. pres. int. techn. Conf. Cons. liv. Resources of the Sea, Rome 1955 (A conf. 10/7), United Nations: 266–89.

Moiseev, P. A., 1956b. "Some data on the fishery of the Chinese Peoples Republic". Moscow, 24 pp. (In Russian.)

Norman, J. R., 1934. "A Systematic Monograph of the Flatfishes (Heterosomata)". 459 pp. British Mus. London.

Mukhacheva, V. A., & Zvyagina, O. A. (In press.) "Development of the Pacific cod, *Gadus macrocephalus* Til". Trans. Inst. Okeanol. USSR. (In Russian.)

Murray, J., & Hjort, J., 1912. "The Depth of the Ocean". London, 821 pp.

Pertseva-Ostroumova, T. A., 1953. "Some new data on the development of flatfishes (fam. Pleuronectidae)". C. R. Acad. Sci. USSR, **91**: 973–76. (In Russian.)

Pertseva-Ostroumova, T. A., 1955. "Key for the identification of pelagic eggs of fishes of the Bay of Peter the Great". Bull. Pacif. sci. Fish. Inst., **43**: 43–68. (In Russian.)

Rass, T. S., 1948. "World Fishery". Moscow, 64 pp. (In Russian.)

Rass, T. S., 1950. "Geographical complexes of the world fishery". Proc. Geogr. Soc. USSR, **83**: 312–17. (In Russian.)

Marine Atlas, vol. 2, 1953. USSR Navy. Maps 16–17, 25–31. (In Russian.)

Shokalskiy, J., 1917. "Oceanography". Petrograd, 608 pp. (In Russian.)

Statistical Bulletin, Int. Comm. Northwest Atl. Fish., 1955. Vol. 3, for the year 1953.

Svetovidov, A. N., 1948. "Gadoids". Fauna USSR, Fishes, **9** (4): 1–222. (In Russian.)

Svetovidov, A. N., 1952. "Clupeidae". Fauna USSR, Fishes, **11** (1): 1–331. (In Russian.)

Yearbook of Fishery Statistics, 1954–1955, 5: FAO, 1956.

Yearbook of Fishery Statistics, 1955–56, 6: FAO, 1957.

Wiborg, Kr. Fr., 1954. "Forekomst av fiskeegg og -yngel. Nord-norske farvann våren 1952 og 1953". Fiskeridir. Småskr., 1: 1–18.

Zenkevich, L. A., 1947 and 1951. "Fauna and Biological Productivity of the Sea". Vols. 1 and 2, pp. 1–506, 1–588. Moscow. (In Russian.)

An Instance of Natural Mass Mortality of Larval Frigate Mackerel in the Hawaiian Islands

By

Donald W. Strasburg

United States Fish and Wildlife Service, Honolulu, Hawaii

Introduction

Mass mortality among larvae of the more fecund marine fishes has been commonly hypothesized but is poorly documented. Early workers ascribed a high death rate to the yolk-sac absorption stage (FABRE-DOMERGUE and BIÉTRIX, 1897; HJORT, 1914, 1926), but recent investigators have instead indicated a considerable mortality at the larva-postlarva transformation point (SETTE, 1943; MARR, 1956, on AHLSTROM and NAIR's MS.).

The existence of a critical period in the early life history has been discredited by AHLSTROM (1954), who states that the apparent mortality might be an artifact produced by net selection, and by MARR (1956), who presents a comprehensive review of the subject. MARR concludes that there is little evidence to support the critical period theory, that records of the natural occurrence of dead larvae may be artifacts, and that where mortalities are restricted in time the causes should be obvious. He qualifies this last idea by saying that "... the chances that the observer will make the right observations at the right time and the right place are greatly reduced".

This paper documents an apparently rarely observed phenomenon, the occurrence of large numbers of dead marine fish larvae. Because of the doubt which has been cast upon a natural mortality of this sort, and because of the slight chances for observing it, it is desirable to present detailed descriptions of the fish, the sampling methods, and the environment at the time of sampling. Particular attention has been paid to the question of whether the larvae were actually dead when collected.

Methods and Descriptions

During 1956 and 1957 the Pacific Oceanic Fishery Investigations (POFI), of the United States Fish and Wildlife Service, Honolulu, tested several types of plankton tows in an attempt to devise a standard method for sampling larval tuna. On 11–13. July 1957, the POFI vessel "Charles H. Gilbert" operated in

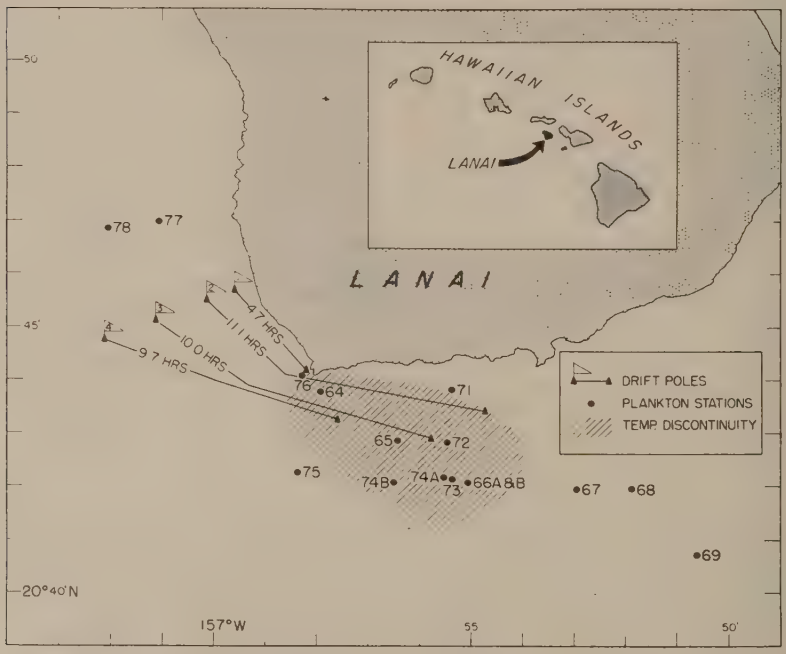

Figure 1. Lanai Island showing stations from which frigate mackerel larvae were obtained, tracks of driftpoles, and area of temperature discontinuity.

the vicinity of Lanai Island, one of the smaller members of the Hawaiian chain (Fig. 1). Here a series of half-hour plankton tows was made with a 1 m (mouth diameter) net, 5 m long and constructed of nylon gauze having mesh apertures 0·66 mm in width in the body of the net and 0·31 mm in the rear section and bag. Horizontal tows were made at the surface and oblique tows from the surface to about 60 m; in the former the net fished just beneath the surface, in the latter it was lowered and retrieved at a slow uniform rate. The vessel's speed was 2·5–3·5 knots during both tows, and the course pursued was frequently circular. A current meter in the net's mouth provided estimates of the volume of water strained. The stations, catches, and other data pertinent to these operations are summarized in Table 1.

At the end of each tow the net was rinsed with salt water to wash plankton residues into the bag. The plankton was immediately transferred to a glass jar and preserved in 10% borax-neutralized formalin. Fish and fish eggs were removed from the surface samples two weeks after collection, and from the 0–60 m samples six weeks after collection, and these were also stored in 10% neutralized formalin. At no time was there any evidence of putrefaction in the samples.

The larval scombrid fishes sorted from the collections were identified with the aid of MATSUMOTO's two recent papers (1958 and MS.), with the dominant

Table 1

Larval frigate mackerel, *Auxis* sp., captured off Lanai, 11–13. July 1957, in half-hour tows with a 1 m zooplankton net

Station	Depth (m)	Date	Time tow started	North latitude	West longitude	Number of larvae	Larvae per 1000 m^3	Percentage dead larvae	Surface temp. °C	Invertebrate plankton (ml/1000 m^3)
64	0	11	1924	20°43·8′	156°58·0′	77	30·8	6·5	26·6	18·5
65	0	11	2059	20°42·9′	156°56·5′	288	129·1	5·9	26·4	6·5
66A	0	11	2301	20°42·1′	156°55·1′	140	58·3	99·3	26·3	4·1
66B	0	11	2337	20°42·1′	156°55·1′	173	60·4	99·4	26·3	3·9
67	0	12	0100	20°42·0′	156°53·0′	96	41·5	18·8	26·2	5·7
68	0	12	0300	20°42·0′	156°51·9′	65	27·7	4·6	26·2	6·5
69	0	12	0501	20°40·7′	156°50·6′	210	117·6	96·2	26·2	25·5
71	0–54	12	2001	20°43·8′	156°55·4′	43	35·4	0·0	25·8	40·3
72	0	12	2046	20°42·8′	156°55·5′	1557	665·8	12·8[1])	26·5	12·4
73	0–59	12	2201	20°42·2′	156°55·5′	185	113·8	50·3	26·7	20·2
74A	0	12	2233	20°42·2′	156°55·6′	186	78·5	53·2	26·7	7·6
74B	0	12	2306	20°42·1′	156°56·6′	234	102·0	23·9	26·4	10·5
75	0–58	12	2349	20°42·4′	156°58·5′	6	3·4	16·7	26·3	18·0
76	0–62	13	0035	20°44·2′	156°58·3′	138	86·9	10·9	26·4	19·8
77	0–82	13	0133	20°47·2′	157°01·0′	30	20·9	6·7	26·2	27·8
78	0–77	13	0221	20°47·1′	157°02·0′	65	39·5	7·7	26·2	28·9

[1]) Based on a subsample of 635 fish.

form being frigate mackerel (*Auxis* sp.). The larvae of the two species of frigate mackerel occurring in Hawaii (*thazard* and a *thynnoides*-like form) are not as yet separable, and it is not known whether more than one species occurred in the Lanai collections. Not only were large numbers of frigate mackerel larvae obtained, but in many cases the specimens appeared to have been dead prior to capture. The correctness of this supposition is discussed in the following paragraphs.

Assessment of Mortality

When first examined the larval frigate mackerel were viewed against a black background with direct, overhead illumination. It was immediately noticeable that there were two distinct types: clean-cut larvae of normal appearance, and imperfect specimens with signs of physical deterioration. Further examination led to the hypothesis that these types represented fish which were alive and dead, respectively, just prior to capture. With this idea in mind all specimens were examined against a black background, and categorized as living or dead on the basis of the following characteristics: —

Living – flesh cream-coloured, opaque; vertebral column visible as a grey line separating epaxial and hypaxial musculature; visceral mass and anus turgid; eyes, jaws, and gill arches usually intact; body frequently contorted.

Dead – flesh grey, somewhat translucent; vertebral column invisible; visceral mass often lacking, when present both it and anus flabby; eyes typically absent; lower jaw prognathous; gill arches distorted; body straight.

Typical representatives of these two types are shown in Figure 2. The colour and transparency of the flesh of the "dead" fish suggest decomposition, as does the lack of eyes and distortion of the gill arches. However, the latter effects

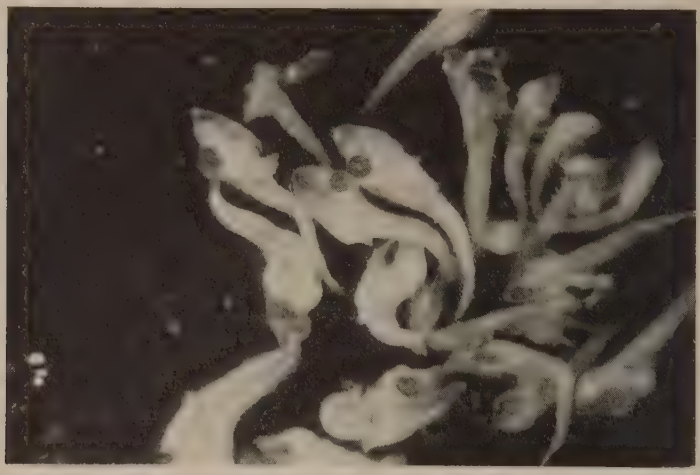

Figure 2. Typical larval frigate mackerel from Lanai. The light coloured specimens to the left were regarded as living, the darker fish to the right as dead.

could also be caused by net damage. The straightness of the body, which stands in marked contrast to the contorted attitudes of the most perfect and fresh looking larvae, implies considerable muscular relaxation, a phenomenon associated with death, at the time of preservation. The loss of the visceral mass could similarly be related to death and putrefaction, with the bloated viscera rupturing the body wall and ultimately tearing free. An increase in buoyancy, brought about by the accumulation of the gases of decay, is a logical mechanism by which dead larvae would remain at the surface to be collected. It should be noted that these larvae do not have swimbladders.

Before accepting the above hypothesis it is necessary to examine several possible causes for the condition of the damaged and "dead" larvae. MARR (1956) noted that damaged larvae were common in plankton samples containing hard, sharp animals such as pteropods, and that another common source was contamination from a previous haul owing to inadequate washing of the net. To investigate the damage caused by hard-bodied animals, counts were made of all pteropods occurring at Stations 66B and 71, where frigate mackerel mortality was 99·4 and 0·0 %, respectively. The total number of pteropods was 22 for Station 66B, and 115 for Station 71, a reverse trend from what would be expected if pteropods damaged the larvae. Neither was damage proportional to the invertebrate plankton volumes obtained (Table 1), for no correlation was found when the plankton volumes were plotted against percentage mortality. It was concluded that the presence of other organisms in the catch had little to do with the condition of the larval frigate mackerel.

As stated earlier, the net was washed between tows so that few organisms could have persisted to contaminate later samples. Examination of the stations listed in Table 1 reveals that a catch showing a heavy mortality sometimes followed one of numerous normal fish, but that several stations were notably at variance with this. Thus Stations 66A and 66B were successive and had

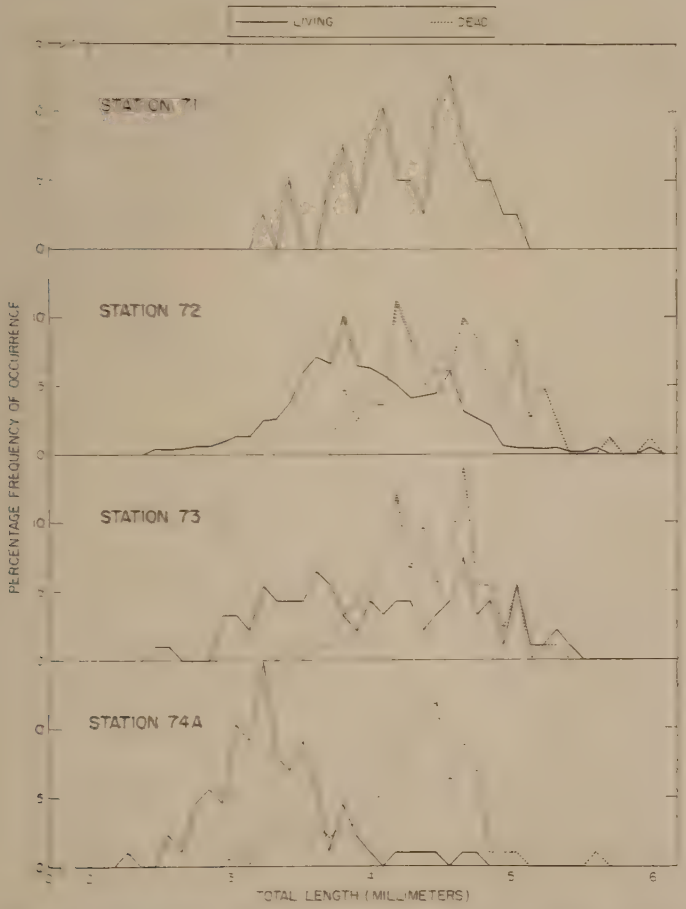

Figure 3. Length-frequency distribution of frigate mackerel at stations showing heavy mortality. Data derived from following numbers of fish: Station 71, 39 living; Station 72, 554 living, 81 dead; Station 73, 92 living, 92 dead; and Station 74A, 87 living, 99 dead.

equally high mortalities, as did Stations 73 and 74A, and Station 76 had an appreciable mortality, yet followed Station 75 where only 6 larvae were captured.

Another line of evidence tending to discredit contamination deals with the length-frequency distribution of the living and dead larvae. Here, total length was measured with the aid of an ocular micrometer, using the snout tip and the end of the longest caudal ray as reference points. Measurements were made to the nearest micrometer subdivision (0·095 mm) and subsequently converted to millimetres. Rather complete overlaps were found in length frequency for

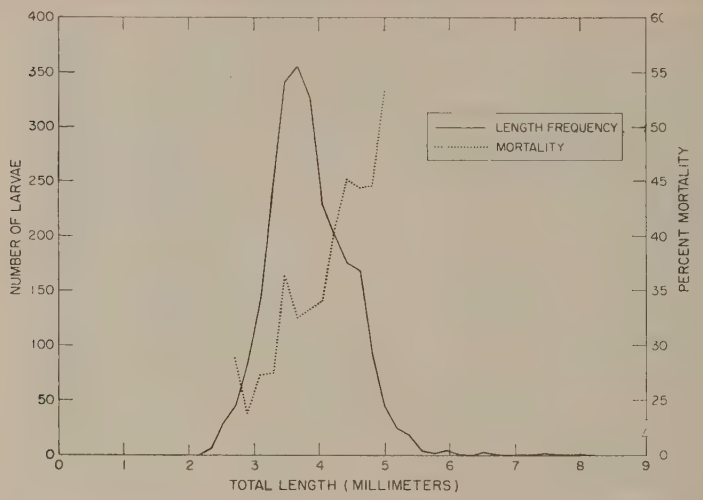

Figure 4. Length-frequency distribution of frigate mackerel, and percentage dead at various lengths. Length data derived from 2561 living and dead specimens; mortality figures based upon 2459 specimens.

Stations 64 through 69, but for Station 71 through 78 there was evidence that the dead fish were not from the same length populations as the living ones. Figure 3 shows that although the dead larvae taken at Station 72 could have been carry-overs from Station 71, there is little likelihood that those in Station 73 persisted from Station 72, or that those in Station 74 A were remnants from Station 73.

If the occurrence of the dead larvae was actually due to contamination then one would expect the mortality at a given length to be proportional to the number of fish of that length. That this is not so is shown by Figure 4, which depicts the mortality at each length category (a subsample was studied from Station 72, and mortality was not calculated for the smaller samples). Mortality is seen to increase with size, with fish about 5 mm in total length being most severely afflicted. As noted by STRASBURG (MS.), tuna larvae of 5 mm and larger are not often caught in plankton nets, probably because of their increased ability to avoid the net, so that their present capture may have been possible because they were dead.

A simple experiment was performed to determine if decomposing larval tuna would ultimately have the appearance of "dead" larvae. The plankton from several night surface tows was frozen after collection, thawed in the laboratory, and sorted in dishes placed in bowls of ice. Twenty-seven larval tuna (19 *Neothunnus macropterus*, 7 *Auxis* sp., and 1 *Katsuwonus pelamis*) were obtained, and these were examined and their appearance noted. Seven representative specimens were then preserved in formalin and the balance allowed to decompose in dishes of sea water over a period of nearly 47 hours at room temperatures of 23°–29°C. The decomposing specimens were re-examined at intervals and samples were preserved periodically. When all specimens had been preserved they were set aside for one week and then categorized as living or dead using

Table 2

Effects of decomposition upon appearance of larval tuna

Time sample preserved	Appearance of larvae (L = living, D = dead, L^1 and D^1 are intermediates)
10 min.....	4 L, 1 L^1, 1 D^1, 1 D
3 hr., 10 min.....	2 L, 2 D^1
6 hr., 45 min.....	2 D^1, 2 D
22 hr., 20 min.....	1 L^1, 3 D
30 hr., 55 min.....	1 L^1, 4 D*)
46 hr., 45 min.....	1 L, 2 D*)

*) Specimens badly deteriorated.

the criteria listed above. The effects of decomposition upon the appearance of these larvae are shown in Table 2 from which it is apparent that a "dead" appearance was generally acquired after 3–6 hours of decomposition. Some specimens, however, had a "living" aspect after 31 hours, and an unusually large fish (a 9·5 mm *Neothunnus macropterus*) appeared "living" after nearly 47 hours. Another larva appeared "dead" both at the start of the experiment and after a week in formalin.

Decomposition seems to be the agent responsible for the difference in appearance between the living and dead specimens. In this connexion it should be noted that decomposition in still water did not result in loss of the visceral mass, although it did cause a considerable loosening of that structure. Presumably the dead specimens taken at sea lost their viscera from agitation by waves or by the plankton net. It was also of interest that no experimental specimens bloated as decay progressed. This does not necessarily eliminate bloating-induced flotation as the mechanism responsible for dead larvae being caught at the surface, for apparently some fish decompose without rising to the surface (DENCE, 1956).

Causes of Death

In natural conditions an increase in the abundance of organisms is thought to be depressed by a system of checks and balances: predation, disease, competition, and the suitability of the physical environment. Predation can be excluded from the present case because it would have resulted in the recovery of no larvae or of larvae with some signs of natural mutilation. The agency involved instead appears to be generalized, for it afflicted a relatively wide size range of larvae, and was apparent over a distance of 12·5 miles and through a time interval of 29 hours.

Gross external examination of about 300 specimens (living and dead in about equal numbers) revealed no signs of disease, but it should be remembered that disease would not necessarily have external manifestations, and that slight symptoms could have been overlooked. No parasites were encountered on the gills, integument, or mouth surfaces, nor were any found internally.

About 500 living and dead larvae were examined for ingested food, with about 50 being dissected and the remainder viewed against a strong light which rendered them quite transparent. No food items were found in the digestive tract of any specimen, but in two cases the intestine was so bloated that the body wall bulged laterally, and when opened was found to be filled

with viscid white fluid. Those fish examined for the presence of food had been captured in the evening, at night, and at dawn, so that the lack of food in their stomachs may only mean that young frigate mackerel are daytime feeders. As can be seen from Table 1, no daytime samples were collected.

There is no way of determining if the mass death was caused by starvation. All specimens were past the "critical" period of yolk-sac absorption, and presumably had already begun feeding on planktonic food. Neither the type of food consumed nor its availability during the sampling period is known. There should be competition for food between individual frigate mackerel larvae and possibly also between them and various other members of the zooplankton. The invertebrate portion of the latter, however, was not over abundant in the samples collected, for the mean catch, 16·0 ml of plankton per 1000 m^3 of water strained was equal to, or less than, comparable Hawaiian plankton samples reported upon by KING and HIDA (1954, 1957). Thus if starvation were the cause of death it might have been induced by intra-specific competition or lack of a critical supply of the right sort of food.

POFI is continuing its studies of the Lanai area for several reasons, one of which concerns a water temperature discontinuity in the region from which the present samples came (Figure 1). In the discontinuity zone surface temperatures varied as much as 1·5°C in approximately one mile, and the surface was frequently characterized by floating terrestrial debris. As pointed out by MATSUMOTO (1958) and STRASBURG (MS.), larval frigate mackerel migrate to the surface at night, and would then be in a region of rapid temperature change at Lanai. Figure 1 also shows the discontinuity area to lie in the path of a current flowing south-easterly or easterly at a speed of about 0·5 knots.

It is to be noted that the upstream stations (Nos. 64, 65, 75–78) had frigate mackerel mortalities ranging only from 5·9% to 16·7%, whereas at certain downstream stations (Nos. 66A, 66B, 73–74B) mortality ranged from 23·9 to 99·4%. Although not true of all stations, it would seem that passage through the discontinuity area was directly related to mortality.

The location of the principal death site can be roughly calculated by means of the known decomposition rate and current speed. A 0·5 knot current would flow 1·5–3 miles in the 3–6 hours necessary for larvae to assume a "dead" appearance by decomposition. In the case of the stations showing the heaviest mortality (Nos. 66A and B), this could place the death site at or near the north-western edge of the discontinuity area. Current drift could also account for the appearance of large numbers of dead larvae downstream from the discontinuity area (Station 69). The lack of high mortality at such stations as 67, 68, and 72 is presently inexplicable.

Summary

1. The mass death of larval marine fish has been the subject of much speculation but has remained largely undocumented. The present paper deals with a series of Hawaiian plankton samples containing 3,493 larval frigate mackerel (*Auxis* sp.), large numbers of which were thought to be dead before capture.

2. The appearance of the dead larvae was markedly different from that of the living fish, and these differences could logically be associated with death prior to capture. Deterioration of the dead fish was probably not brought

about by contact with hard, sharp organisms, or by the fish remaining in the net between hauls. The length-frequency distributions and the percentage mortality of various length groups also discredited contamination of this sort. Fresh larvae allowed to decompose attained a "dead" appearance in from 3 to 6 hours.

3. The definitive cause of death could not be determined. There were no signs of predation, disease, or parasitism, but starvation could not be definitely excluded as a factor. It was tentatively hypothesized that the mass death was brought about by passage through an area having marked discontinuities in its surface water temperature.

References

Ahlstrom, E. H., 1954. "Distribution and abundance of egg and larval populations of the Pacific sardine". Fish. Bull., U.S., **56** (93): 83–140.

Dence, W. A., 1956. "Concretions of the alewife, *Pomolobus pseudoharengus* (Wilson), at Onondaga Lake, New York". Copeia, 1956: 155–58.

Fabre-Domergue, & Biétrix, Eugène, 1897. "La période critique post-larvaire des poissons marins". Bull. Mus. Hist. Nat. Paris, **3**: 57–58.

Hjort, J., 1914. "Fluctuations in the great fisheries of northern Europe viewed in the light of biological research". Rapp. Cons. Explor. Mer, **20**: 228 pp.

Hjort, J., 1926. "Fluctuations in the year classes of important food fishes". J. Cons. int. Explor. Mer, **1**: 5–38.

King, J. E., & Hida, T. S., 1954. "Variations in zooplankton abundance in Hawaiian waters, 1950–52". U.S. Fish Wildl. Serv., Spec. sci. Rep.-Fish., 118: 66 pp.

King, J. E., & Hida, T. S., 1957. "Zooplankton abundance in Hawaiian waters, 1953–54". U.S. Fish Wildl. Serv., Spec. sci. Rep.-Fish., 221: 23 pp.

Marr, J. C., 1956. "The 'critical period' in the early life history of marine fishes". J. Cons. int. Explor. Mer, **21**: 160–70.

Matsumoto, W. M., 1958. "Descriptions of larvae of four species of tuna and their distribution in central Pacific waters". Fish. Bull., U.S., **58** (128): 31–72.

Matsumoto, W. M. "Descriptions of *Euthynnus* and *Auxis* larvae taken by the 'Dana' and other Danish vessels, 1911–1938". MS.

Sette, O. E., 1943. "Biology of the Atlantic mackerel (*Scomber scombrus*) of North America. Part I: Early life history, including the growth, drift, and mortality of the egg and larval populations". Fish. Bull., U.S., **50** (38): 149–237.

Strasburg, D. W. "Quantitative estimates of larval tuna abundance, with critical comments on sampling". MS.

Investigations on 0-Group Herring

By

R. J. Wood

Fisheries Laboratory, Lowestoft

Introduction

The herring populations with which English investigators are chiefly concerned spawn during the autumn and winter months in the southern region of the North Sea, they deposit their eggs on the sea bed and hatching takes place some 1–3 weeks later. During the early stages of development the herring larvae live and drift about in the plankton until they reach a size at which they are capable of independent movement. After this stage has been reached, however, the herring larvae, like the young of many other species of fish, tend to gather in the shallow water near the coasts, and it is here that they pass through the metamorphosis, becoming completely scaled and acquiring the adult form (BÜCKMANN, 1950). During this period the herring form part of the "Whitebait" community ("Whitebait" being a mixture of young herring and sprats) which is fished commercially in a few places such as the Thames Estuary. Later on, as they grow older and larger the herring move offshore into deeper water where they become liable to capture in such immature herring fisheries as that of the Bløden Ground.

Apart from the "Whitebait" fishery, the young herring are not exploited commercially in English waters, and it is not surprising therefore that at other times they are seldom seen except when captured with special gears such as those used in these investigations. The study of the young herring during the "Whitebait" phase is of obvious importance from the point of view of the distribution and identity of stocks, and it is with this period when the herring are less than one year old (i.e., 0-group) that this paper is chiefly concerned.

HODGSON (1929) published the results of investigations carried out between Blyth and the Thames Estuary during the period 1922–1928, and also those from earlier investigations made by Dr. W. WALLACE on the young herring caught in the commercial whitebait fishing of the Thames Estuary from 1913–1918. By plotting the length modes of the samples in relation to the time of year at which they were caught, HODGSON was able to distinguish three broods amongst the 0-group herring population occurring in the inshore waters along the English east coast. They were designated the 7–8 cm, 9–10 cm, and 12 cm groups, these lengths being roughly the modal lengths of the three broods

during their second winter. HODGSON concluded that these differences in length were most probably due to differences of age, and estimated the respective ages to be approximately 12, 14–15, and 16–17 months, and the spawning times as late November–January or February, September–October, and July–August.

Occasional samples of 0-group herring were obtained at Lowestoft from 1947–51, but extensive investigations were not again carried out along the English east coast until 1953–55. The present paper describes the results of these more recent investigations.

Collection and Treatment of Samples

The main instrument used to collect samples of 0-group herring was the beach seine, the construction and operation of which were described by HODGSON (1929). From each haul a sample of the catch was measured for length and in many cases also examined for number of vertebrae. The urostyle was always included in the vertebral counts, being counted as the last vertebra.

Offshore samples of 0-group herring, unfortunately few in number, were obtained with various gears. These were: —

(1) Commercial bottom trawls with fine meshed covers on the cod-end, etc.
(2) Small plaice trawl fished from R. V. "Onaway". (1 inch internal mesh, possibly slightly selective.)
(3) Petersen young-fish trawl. (Only successful within 3 miles of coast.)
(4) Small meshed drift-nets (47–73 rows per yard.)
(5) Larsson midwater trawl.

All the offshore catches were treated in a similar manner to those obtained with the beach seine.

Identification of Young Herring

The identification of post-larval and metamorphosing herring (from about 3–5 cm in length) required considerable care until experience had been gained in this field, due to the fact that sprats, and occasionally pilchards, of similar size were often present in the samples. The identification was further complicated by the inclusion in a number of samples of summer spawned herring which had very low vertebral counts, some of which were within the range found in pilchards.

For the identification of the young clupeoids caught during these investigations, the myotome count in the trunk region, as advocated by LEBOUR (1921), was found to be an unreliable criterion for positive identification of herring and pilchards because of the similarity of the counts in both pilchards and summer spawned herring; moreover, it was extremely difficult to be certain which was the first and which the last myotome to be counted.

In any doubtful cases positive identification of sprats was achieved by counting the total number of vertebrae, but for herring it was necessary to note the position of the dorsal and pelvic fins and the anus, in relation to the numbered vertebrae. In all broods, other than the one spawned in summer, these corresponded extremely closely with the positions given by LEBOUR (1921) and FORD (1930) for herring. The positions of fins and anus for summer spawned

Table 1

Beach seine samples of 0-group herring from the English east coast, 1953–55

Length range A is range of complete sample.
Length range B is range of group of fish on which vertebral counts were made. Numbers of herring on which vertebral counts were made are given in brackets.

Month	Locality	Date	Length range A (cm)	Modal length (cm)	Length range B (cm)	Mean Vert. S.
Apr.	Lowestoft	29.4.54	3·0–5·4	4·06	3·0–5·4	56·696 (79)
May	Amble	11.5.54	4·0–5·5	4·72	4·0–5·5	56·550 (100)
	Sunderland	13.5.54	4·0–9·4	6·49	–	–
	–	30.5.55	3·5–5·4	4·72	3·5–5·4	56·538 (39)
			6·0–8·9	7·29	6·0–8·9	56·538 (65)
	Hartlepool	14.5.54	4·0–7·4	4·70	–	–
	–	31.5.55	3·5–7·4	4·85	–	–
				6·10	–	–
	Scarborough	15.5.54	4·5–7·9	6·05	5·0–6·9	56·590 (100)
	–	17.5.54	4·0–7·9	4·74	4·0–5·4	56·567 (60)
				6·50	5·5–7·9	56·510 (100)
	Bridlington	20.5.54	3·0–9·9	5·94	4·5–7·9	56·481 (106)
	Spurn Point	23.5.54	3·5–6·9	4·30	–	–
	Lowestoft	27.5.54	3·0–6·0	4·17	3·0–5·4	56·700 (100)
June	Scroby Sands (off Gt. Yarmouth)	4.6.54	4·5–9·4	7·73	6·5–9·4	56·460 (100)
	Lowestoft	16.6.55	3·5–8·4	4·38	3·5–5·9	56·643 (185)
				7·20	7·0–7·9	56·660 (53)
	–	21.6.55	3·0–7·4	4·12	–	–
	–	27.6.55	3·0–7·4	4·17	3·0–5·9	56·672 (119)
July	Blyth	21.7.54	3·0–8·4	3·99	3·0–5·4	57·059 (102)
				6·29	5·5–7·9	56·626 (115)
	Sunderland	22.7.54	3·5–9·4	3·93	–	–
				7·06	6·0–7·9	56·590 (100)
	Hartlepool	22.7.54	3·5–9·9	4·14	–	–
				6·62	–	–
	Scarborough	24.7.54	3·5–9·9	6·83	5·0–7·4	56·510 (104)
				8·17	7·5–9·4	56·698 (53)
	Bridlington	25.7.54	3·5–9·4	6·03	5·0–7·4	56·521 (144)
				8·14	7·9–8·9	56·750 (64)
	Lowestoft	3.7.54	3·5–10·9	5·64	4·0–6·9	56·978 (137)
				7·93	–	–
	–	13.7.55	2·5–9·9	5·29	3·5–6·4	56·711 (152)
				7·14	6·5–7·9	56·747 (75)

herring having 53, 54, 55, and 56 vertebrae do not appear to have been described elsewhere and are given in an appendix at the end of this paper.

Results

Details of all the main samples of 0-group herring collected inshore during these investigations are given in Table 1. They are set out by months according to the position of capture along the English east coast from north to south. The modal lengths and mean vertebral numbers have been calculated for the largest catch occurring during hauls on the date stated; if the numbers of herring caught in any one haul were insufficient, calculations were made from a number of hauls combined.

During these investigations 0-group herrings were found to be fairly abundant inshore along two stretches of the English east coast: —

Table 1 continued.

Month	Locality	Date	Length range A (cm)	Modal length (cm)	Length range B (cm)	Mean Vert. S.
August	Berwick	28·8·55	5·0–10·9	6·37	5·0–7·4	56·584 (113)
	Amble	31.8.55	5·5–12·4	7·30	–	–
	Blyth	26.8.55	6·5–10·4	8·36	–	–
	Sunderland	25.8.55	6·0–11·9	7·79	–	–
	Hartlepool	24.8.55	5·5–10·9	7·35	5·5–9·9	56·660 (100)
	Scarborough	13.8.53	6·5–10·4	8·21	7·0–10·4	56·471 (121)
	–	20.8.55	6·0–10·4	7·23	6·5–8·4	56·680 (50)
	Bridlington	10.8.53	6·0–11·4	7·64	6·0–10·4	56·516 (124)
		19.8.55	5·5–10·4	7·13	5·5–7·9	56·735 (102)
	Withernsea	18.8.55	3·0–14·4	7·00	–	–
				8·50	–	–
	Mablethorpe	9.8.53	2·5–6·9	3·59	2·5–6·9	55·367 (120)
			7·5–10·4	9·30	7·5–10·4	56·548 (31)
	–	13.8.54	3·0–8·9	4·20	3·0–5·4	55·000 (100)
				7·43	6·0–8·9	56·712 (111)
	Skegness	13.8.54	3·0–13·4	8·10	7·0–8·9	56·910 (100)
	–	17.8.55	2·0–5·9	2·89	2·5–5·9	54·900 (40)
			6·5–13·4	8·73	6·5–11·9	56·562 (185)
	Lowestoft	4.8.53	3·0–11·4	3·78	3·0–4·9	55·211 (76)
				7·16	5·5–8·9	56·893 (84)
	–	5.8.54	3·5–8·9	6·17	5·0–8·4	56·980 (100)
	–	15·8·55	3·0–9·9	4·91	3·5–6·4	54·740 (50)
				7·25	7·0–9·9	56·704 (125)
	–	19.8.54	4·5–11·4	6·52	–	–
	Orfordness	2.8.55	3·5–7·9	4·31	3·5–5·9	55·000 (24)
	–	17·8·54	5·5–8·4	7·24	6·0–8·4	56·960 (100)
	Brightlingsea	3.8.55	2·5–7·4	3·39	3·0–5·4	54·933 (30)
	Deal	4.8.55	2·5–11·4	3·28	3·0–4·9	54·643 (28)
				6·77	5·0–8·9	56·835 (109)
Sept.	South Shields	2.9.55	6·5–10·9	8·90	7·0–10·4	56·520 (100)
	Lowestoft	5.9.53	4·0–11·4	6·07	4·0–6·9	55·196 (102)
				8·08	7·5–11·4	56·729 (96)
	–	16.9.55	5·0–10·9	6·15	5·0–6·9	54·767 (30)
				7·91	7·0–10·4	56·784 (134)
Oct.	Lowestoft	2.10.53	4·0–11·9	6·15	4·0–6·9	55·137 (102)
				8·33	8·0–11·9	56·727 (88)
	–	21.10.54	5·0–9·9	6·99	5·5–8·4	56·920 (100)
	–	28.10.55	6·5–10·4	8·35	8·5–10·4	56·714 (35)
Dec.	Lowestoft	2.12.55	6·5–10·4	7·33	6·5–7·4	54·640 (25)
				8·32	8·0–10·4	56·747 (99)
	–	18.12.54	6·0–11·4	7·15	6·0–9·0	56·921 (38)
	Scroby Sands (off Gt. Yarmouth)	30.12.53	3·0–6·4	4·32	3·0–6·4	56·623 (61)

(1) The northern region from Bridlington Bay to Berwick.
(2) The southern region along the East Anglian coast and southwards as far as Deal.

Only small numbers were caught in the intervening region which includes the Wash, the Lincolnshire coast and the Yorkshire coast, south of Bridlington Bay.

In Figure 1, the mean vertebral numbers of the inshore samples have been plotted against the time of year at which they were obtained. Samples from the northern, intermediate, and southern regions have been indicated separately, as also have the main and minor modes. Four facts of importance should be observed.

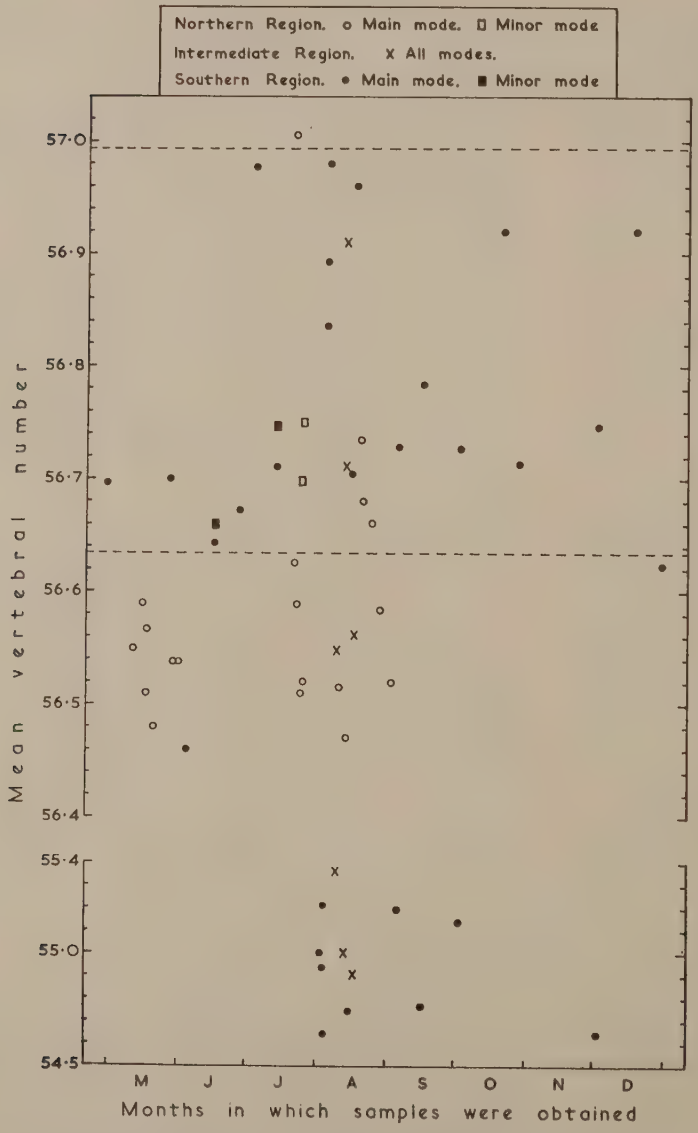

Figure 1. Distribution of mean vertebral numbers. Inshore 0-group herring samples 1953–1955.

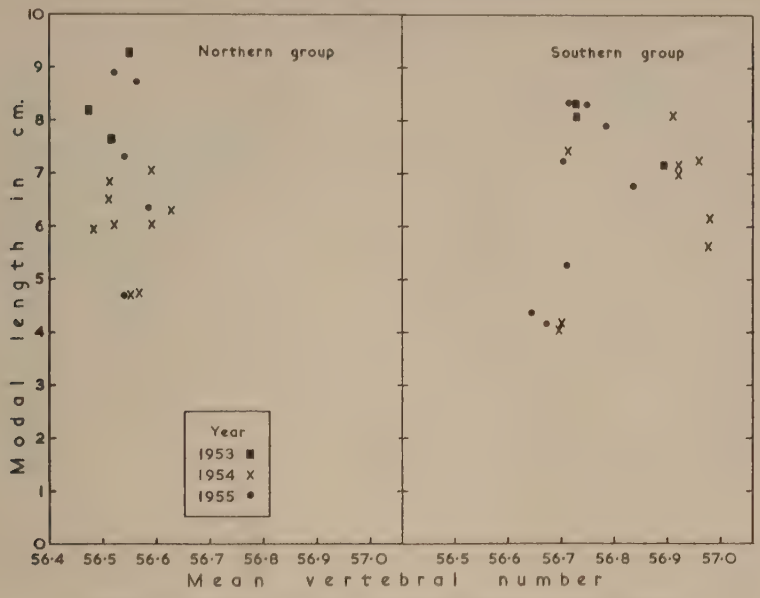

Figure 2. Distribution of mean vertebral numbers by modal length.

(1) A number of samples from both the southern and intermediate regions (but none from the northern region) have very low mean vertebral numbers within the range 54·643–55·367.
(2) Twenty out of twenty-two of the remaining samples from the southern region have mean vertebral numbers within the range 56·643–56·980.
(3) Fifteen out of twenty-one samples from the northern region have mean vertebral numbers within the range 56·471–56·626. Of the six outside this range, the one with mean vertebral number 57·059 towards the end of July had a modal length of 4 cm and so was obviously spring spawned.
(4) The intermediate region, as would be expected, is an area in which herring from either the northern or southern region are found mixed together.

Mixing is not, however, entirely confined to the intermediate region. The 5 northern and 2 southern samples, which have mean Vert. S. outside the range covered by the rest of the samples from their respective regions, are probably connected with the Vert. S. groups in which they are placed. This is evident particularly from the modal lengths of each of these 7 samples.

In Figure 2, the modal lengths of the two main groups which occur in either the northern or southern regions are plotted against mean vertebral number, and the year in which each sample was obtained is indicated. It will be noted that there is no change in the mean vertebral number of the northern group during growth between 4·6–9·3 cm (the length range covered by samples in this region). In the southern group, taking the years separately, there is a marked increase in mean vertebral number which occurs chiefly between 4 cm and 5 cm.

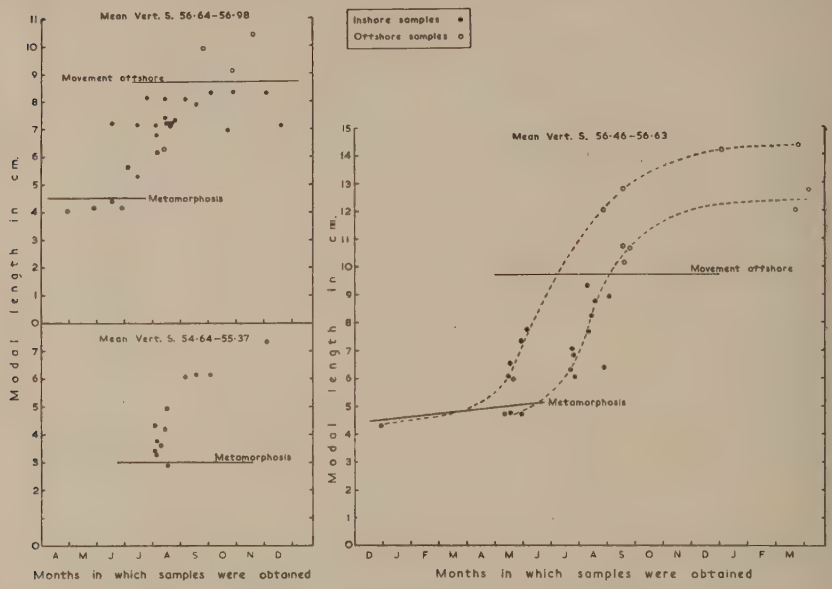

Figure 3. Length distribution of samples within the three main vertebral ranges.

In the spring, when 0-group herring begin to become abundant in the inshore waters of the southern region, the modal length shows little sign of increasing for several weeks, while the mean Vert. S. increases. This indicates that smaller and later spawned larvae must continuously be moving in during this period. An exceptionally large increase in mean Vert. S. took place in 1954, during the period in which the modal length of this group increased from 4·2–5·6 cm. The latter sample had mean Vert. S. 56·978 and must have been composed mainly of herring which had been affected by very low temperatures during the critical stage of development when the number of vertebrae is fixed. In fact, very low surface temperatures did occur in January 1954 off the Belgian coast, and this might well have been the cause of the very high mean Vert. S. of all the subsequent samples from the southern region of that year.

In Figure 3, the modal lengths of all the samples falling within the three main vertebral ranges indicated in Figure 1, have been plotted against time. In this figure are also plotted the modal lengths of the offshore samples, listed in Table 2, which have mean vertebral numbers within the same three ranges. The size at which metamorphosis occurs is also indicated and so is the probable size at which the movement offshore is completed.

Herring with mean vertebral numbers within the range 54·64–55·37 first appear inshore, in any quantity, at the beginning of August when their modal length is between 3–4 cm. Metamorphosis is completed by about 3 cm. A rapid increase in modal length takes place during the next few months, and this may exceed 7 cm by the beginning of December. Only occasionally have herring of this group been found in the offshore samples.

Table 2

Samples of 0 and I-group herring from the southern North Sea, 1954–1957

Date	Position	Gear*	Length range of catch (cm)	Calculated modal length (cm)	Length range of vertebral sample (cm)	Mean Vert. S.
20. 7.57	15′ NExE of Tyne	DN	8·8–12·2	Total catch 8 herring from one net		
5. 8.54	¼ mile off Lowestoft....	PYFT	5·4–6·9	6·13		
5. 8.54	3 miles off Lowestoft...	–	5·5–7·4	6·62		
9. 8.54	½ mile off Yarmouth ...	–	6·0–9·4	6·75		
12. 8.54	¼ mile off Winterton....	–	5·5–6·9	6·30	5·5–6·9	56·941 (34)
13. 8.54	¼ mile off Skegness.....	–	7·0–9·4	8·75		
17. 8.54	¼ mile off Orfordness...	–	6·5–10·9	7·35		
17. 8.54	3 miles off Dunwich....	–	6·0–9·4	6·90		
17. 8.54	3 miles off Southwold ..	–	6·0–8·4	6·78		
26. 8.55	3 miles NNE of Coquet Lt. House	DN	10·0–13·9	12·00	10·0–13·9	56·540 (100)
16. 9.56	Filey Bay.....	SPT	9·0–12·9	10·70	9·0–12·4	56·529 (34)
17. 9.56	Bridlington Bay	SPT	9·5–16·9	10·25 12·76	11·5–14·4	56·628 (43)
19. 9.56	Lynn Deeps (Wash)....	SPT	9·0–11·4	10·13	9·1–11·1	56·480 (50)
23. 9.55	Rye Bay.....	CT	8·0–13·4	9·93	8·0–11·9	56·684 (38)
24. 9.55	14′ NNW of Zeebrügge.	CT	9·0–12·4	10·65	9·0–12·4	56·594 (32)
26.10.55	14′ ExS of Lowestoft...	LT	8·0–11·9	9·12	8·0–11·9	56·773 (22)
17.11.55	½ mile off Southwold ...	PYFT	6·5–16·6	10·43	8·5–11·9	56·671 (152)
24.11.54	15 miles NE of Hartlepool	CT	10·0–12·9	11·30	10·0–12·9	57·074 (27)
1. 1.55	Botney Gut.....	CT	12·5–17·4	14·14	12·5–17·4	56·621 (58)
14. 3.56	25 miles NxE of Whitby	CT	13·0–16·9	14·57	13·0–16·9	56·429 (28)
21. 3.54	Botney Gut.....	CT	10·0–17·9	12·00 14·25 15·68	10·0–13·4 13·5–14·9 15·0–16·4	56·613 (119) 56·410 (39) 56·750 (12)
22. 3.56	Cleaver Bank	CT	11·5–16·9	14·33	12·2–16·6	56·515 (66)
5. 4.55	54° 24′ N, 5° 42′ E.....	CT	10·5–16·9	12·75	10·5–15·9	56·635 (196)
10. 5.56	Bridlington Bay	SPT	10·0–16·9	11·86	10·0–13·4	56·667 (60)
11. 5.56	Filey Bay.....	SPT	10·0–15·4	11·88		
15. 6.56	Hamilton Dock	Eel	11·0–15·9	11·89	11·0–12·9	54·769 (26)
	Lowestoft.....	Nets		13·12	13·0–13·9	Only a few fish all 56 & 57 Vert.

* CT: Commercial Trawl; PYFT: Petersen Young-Fish Trawl; DN: Drift-Net; SPT: Small Plaice Trawl; LT: Larsson Trawl. Numbers of herring on which vertebral counts were made are given in brackets.

Herring with mean vertebral numbers within the range 56·46–56·63 are much more complex, and it is quite possible that two separate groups are included within this range. Most of the May samples have a bi-modal length distribution with from 1–3 cm separating the modes. Few of the herring in the smaller modal group have completed the metamorphosis while all of those in the larger modal group are well beyond this stage. There are, moreover, differences of 2 cm between the modal lengths of the offshore samples in both September and March. Herring within this vertebral range first appear inshore when their modal length is in the region of 4 cm. In the December sample metamorphosis had been completed by all the fish over 4·5 cm in length. In the May samples, on the other hand, metamorphosis was not completed until a length of 5 cm had been reached. Movement offshore occurs during the period June–September and appears to be largely completed by the time that a length of 10 cm is reached.

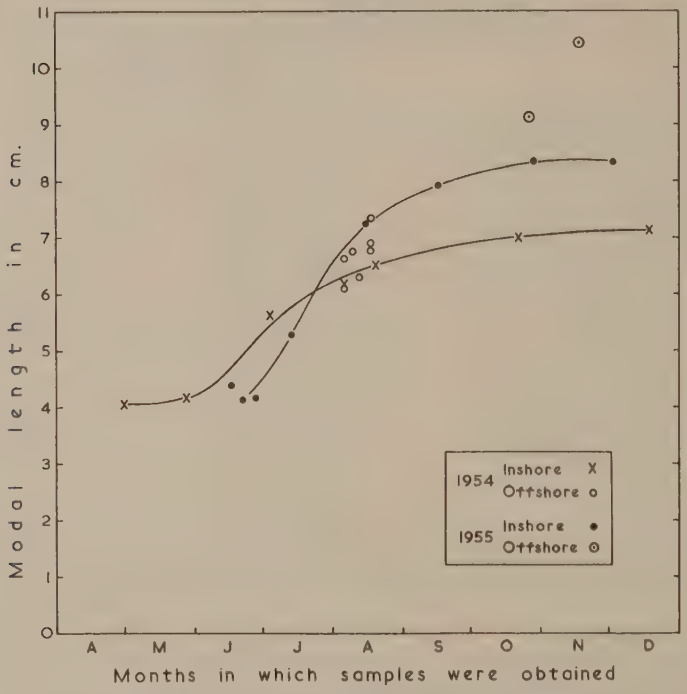

Figure 4. Length distribution of 0-group herring samples obtained inshore at Lowestoft and off the East Anglian coast in 1954 and 1955.

Finally there are herring with mean vertebral numbers within the range 56·64–56·98. These first appear inshore when their modal length is at 4 cm and there is little increase in this modal length for some weeks, metamorphosis is completed at 4·5 cm and the offshore movement between 8·5–9·0 cm.

The considerable degree of scatter in the modal values for this group is largely due to differences which occurred in the samples obtained at Lowestoft in 1954 compared with 1955. These have therefore been plotted separately in Figure 4, together with the offshore samples obtained along the East Anglian coast in both years. It is clear that in 1954 herring of this group had started to move offshore by the end of July, and thereafter the modal lengths of the inshore samples increased very slowly. In 1955, however, no samples were obtained off shore until November, although hauls had been made with small meshed drift-nets and the Petersen young-fish trawl from July–September. The modal length of the inshore samples in 1955 therefore showed a fairly rapid increase up to the middle of September, because all the herring of this group were still inshore up to that time.

Discussion

At least four separate groups of young herring have been identified inshore along the English east coast during these investigations. Two are of little commercial importance. One of these, spring spawned, occurred only in the July 1954 samples, taken in the northern region at Blyth, Sunderland, and Hartlepool. This group is thought to have originated from spawning grounds in the vicinity of the Berwick Banks. The other group, which from its very low vertebral numbers and modal length (3–4 cm in August), appeared to be summer spawned, was found in both the intermediate and southern regions distributed between Mablethorpe and Deal. The existence of this group was noted by HODGSON (1929) but it appears to have become much more abundant in recent years than hitherto. Its origin is not exactly known, but adult herring with similar low vertebral numbers are caught along the East Anglian coasts and in the Thames Estuary during the early part of the year (Feb.–March) at maturity stage IV–V (BOLSTER, 1954).

The remaining groups undoubtedly arise from adult stocks of great commercial importance. The low modal length during May-June and high mean Vert. S. of the group which occurs in the southern region, indicate that this one is probably spawned in winter; moreover the southern region is very close to the well known winter spawning grounds in the vicinity of the Sandettié Bank and at the eastern end of the English Channel. WALLACE (1924) and BÜCKMANN (1950) have also shown that the direction of larval drift from these grounds is in a NE direction between the East Anglian and Dutch coasts. BÜCKMANN (1950) was able to distinguish two groups of larvae of different size from the winter spawning ("Ältere" and "Jüngere Downslarven"). He showed that the bulk of the larger ones, which are probably hatched during November–December, arrive in the German Bight as early in the year as February or March. The smaller larvae, probably hatched during January, do not, however, enter the German Bight in quantity each year, and were in fact missing from that area in 1955 (BÜCKMANN and HEMPEL, 1956).

It is significant that in August 1955 exceptionally large catches of 0-group herring were made at places in the northern region of the English east coast, i. e., Bridlington, Scarborough, and Hartlepool. The modal length and mean Vert. S. of these herring were so similar to those caught in the southern region, that they must almost certainly have had the same origin. It is therefore probable that the group, which is found predominantly in the southern region of the English east coast, is largely composed of herring which originate from the latter part of the winter spawning. This conclusion is to some extent confirmed by the fact that since the numbers of the older and later spawning adult herring of the winter spawning stock have been reduced (CUSHING and BURD, 1957), the abundance of 0-group herring in samples taken at Lowestoft, has shown a marked decline. Beach seine catches of several thousands of herring per haul were often made during the summer months of 1947, but more recently (1953–1955) catches have rarely exceeded 500 per haul. The fact that the very high mean Vert. S. of the 1954 samples was not evident when the whole winter recruit stock entered the East Anglian fishery at 3 years of age, in 1956 could be accounted for if only part of the winter spawned larval stock is sampled along the English east coast.

It has already been pointed out that there are possibly two separate groups of herring distributed in the northern region of the English east coast. It would be unreasonable not to accept that one of these must originate from the very important spawning which takes place along the western and southern edges of the Dogger Bank in the autumn. According to Bückmann and Hempel (1956) the Dogger Bank larvae, which are carried into the German Bight each year, reach a modal length of from 3·0–3·5 cm during March, and metamorphose in the coastal waters during May. The Dogger larvae, from the data given by Bückmann (1950), have an average growth of about 6 mm per month during the period October-March, and would therefore reach a modal length somewhere in the region of 4·2–4·7 cm by May. This size is in fair agreement with the modal length of the smaller herring found in the northern region of the English east coast during May. The larger herring in the northern region at this time, however, if they in fact are a separate group, might well originate from the Scottish east coast autumn spawning which takes place some 1–2 months earlier than the Dogger spawning. It is perhaps significant that a group of exceptionally large larvae (about 4·0 cm long in February and March) are found in the German Bight which Bückmann and Hempel (1957) thought might originate from the late summer spawning in the western part of the middle North Sea.

Summary

1. Investigations were carried out from 1953–1955 on the young herring which frequent the inshore waters of the English east coast during their first year of life. They were found to be abundant along two stretches of coast:—

(a) The northern region — from Bridlington Bay to Berwick.

(b) The southern region — along the East Anglian coast and southwards as far as Deal.

By comparison only small numbers were found in the intervening region.

2. It was possible to distinguish four separate groups of herring in the samples, on the basis of marked differences in mean Vert. S. modal length and geographical distribution.

3. Two groups were of little commercial significance. Of these one which was spring spawned occurred in the northern region, while the other, summer spawned, was found in both the southern and intermediate regions. Of the remaining two groups, one was found chiefly in the northern region and the other in the southern region.

4. The northern group, which metamorphosed inshore during May at a length of approximately 5 cm had largely moved offshore again by the time that a length of 10 cm had been reached during the early autumn.

5. The southern group, which was younger, metamorphosed inshore during June at a length of approximately 4·5 cm. This group had largely moved offshore by the time that a length of 9 cm had been reached during late autumn and early winter.

6. It is most probable that of these two groups the northern originated from the Dogger Bank autumn spawning, and the southern from the latter part of the Downs winter spawning.

7. The possibility exists that a further group was also distributed in the nor-

thern region during May, with a modal length of between 6–7 cm. These herring could have originated from the Scottish east coast autumn spawning, and it seems likely that they moved offshore again during June–July at a length somewhere in the region of 9–10 cm.

APPENDIX

Key for the identification of summer spawned herring

(1) *Herring having 53 vertebrae*

Metamorphosed specimens only.
Anus usually opposite 40th vertebra (range from midway between 38th and 39th to 41st vertebra).
First ray dorsal fin usually opposite point midway between 23rd and 24th vertebra (range 23rd to 25th vertebra).
First ray pelvic fin usually opposite 26th vertebra (only 3 observations).

(2) *Herring having 54 vertebrae*

Metamorphosed specimens only.
Anus usually opposite point midway between 40th and 41st vertebra (range from 39th vertebra to midway between 41st and 42nd vertebra).
First ray dorsal fin usually opposite 24th vertebra (range 23rd to 25th vertebra).
First ray pelvic fin usually opposite point midway between 26th and 27th vertebra (range 26th to 28th vertebra).

(3) *Herring having 55 vertebrae*

Metamorphosed specimens only.
Anus usually opposite 41st vertebra (range from midway between 39th and 40th vertebra to midway between 42nd and 43rd vertebra).
First ray dorsal fin usually opposite point midway between 24th and 25th vertebra (range 23rd to 26th vertebra).
First ray pelvic fin usually opposite 27th vertebra (range from 26th vertebra to midway between 28th and 29th vertebra).
Unmetamorphosed specimen 2·8 cm in length.
Anus opposite 40th vertebra.
First ray dorsal fin opposite 26th vertebra.
First ray pelvic fin opposite point midway between 24th and 25th vertebra.

(4) *Herring having 56 vertebrae*

Metamorphosed specimens only.
Anus usually opposite point midway between 41st and 42nd vertebra (range 41st to 43rd vertebra).
First ray dorsal fin usually opposite 25th vertebra (range 23rd to 26th vertebra).
First ray pelvic fin usually opposite point midway between 27th and 28th vertebra (range from between 26th and 27th vertebra to 29th vertebra).

References

Bolster, G. C., 1954. "Strange herring on the East Anglian coast". Ann. Biol. Copenhague, **10**: 168–69.

Bückmann, A., 1950. "Die Untersuchungen der Biologischen Anstalt über die Ökologie der Heringsbrut in der südlichen Nordsee". Helgoländ. wiss. Meeresunters., **3**: 1–57.

Bückmann, A., & Hempel, G., 1956. "Some results of German investigations on herring larvae". Rapp. Cons. int. Explor. Mer, **143**, Pt. 2: 122–23.

Bückmann, A., & Hempel, G., 1957. "Untersuchungen an der Heringslarvenbevölkerung der Innenjade". Helgoländ. wiss. Meeresunters., **6**: 48–70.

Cushing, D. H., & Burd, A. C., 1957. "On the herring of the southern North Sea". Fish. Invest. Lond., Ser. 2, **20** (11): 1–31.

Ford, E., 1930. "Herring investigations at Plymouth. VIII. The transition from larva to adolescent". J. Mar. biol. Ass. U. K., **16**: 723–52.

Hodgson, W. C., 1929. "Investigations into the age, length and maturity of the herring of the southern North Sea. Part III. The composition of the catches from 1923–1928. Section II. The young herring in the whitebait stage along the east coast of England". Fish. Invest. Lond., Ser. 2, **11** (7): 25–42.

Lebour, M. V., 1921. "The larval and post larval stages of the pilchard, sprat and herring from Plymouth district". J. Mar. biol. Ass. U. K , **12**: 427–57.

Wallace, W., 1924. "First report on young herring in the southern North Sea and English Channel. Part I. Distribution and growth of larval and post larval stages". Fish. Invest. Lond., Ser. 2, **7** (4): 1–84.

The Interpretation of the East Anglian Herring Data, 1924–1955

By

D. H. Cushing and **A. C. Burd**

Fisheries Laboratory, Lowestoft

HODGSON (1958) has criticized our paper (CUSHING and BURD, 1957) in some detail. Because the herring question is of some importance, the criticisms deserve an answer; they were grouped under three heads, Environment, Advance in Maturity, and Mortality Rates. We shall use the same headings for our answers; then we shall briefly consider his hypothesis.

1. Environment

HODGSON has pointed out that the numbers of *Calanus* on the Flamborough Line of plankton stations were the same in 1935, 1948, and 1952 and concludes that the increased growth of the herring by 1952, as compared with earlier years, could not be associated with numbers of *Calanus*. As stated, this is a fair debating point, but we were impressed by the following grouping of the data: —

Year	1935–38	1947–49	1950–54
Average numbers of *Calanus*/m^3 per month	78	88	183

Thus, it seemed likely that the increased size of the herring since 1950 was truly associated with the increase in numbers of *Calanus* since then, which have remained nearly twice as high as the pre-war level in all years up to 1957, except 1956. Further, work about to be published by one of us (A.C.B.) shows a clear relation between L_∞, the asymptotic length of the herring in the Bertalanffy growth equation, and the numbers of *Calanus*/m^3 on the Flamborough Line from 1933–57.

The point has been made that it was the 1947 year-class which first increased in size, succeeded by the following year-classes also composed of big fish, and that this made the association with numbers of *Calanus* doubtful. We agree that increased growth started when the 1947 year-class appeared in 1950, but we do not see the grounds for doubt. We think that the 1947 year-class was com-

posed of large fish because of the very large increase in *Calanus* in 1950; we believe that the succeeding year-classes were also composed of big fish because the numbers of *Calanus* remained higher than before 1950.

Table 1 in CUSHING and BURD (1957) shows increased growth increments from 3/4, 4/5, and 5/6 in 1950/51. This is said to be an illusion based on a true increase in the 1947 year-class, affecting the average lengths of the older fish with which whey were swimming. It is hard to imagine the operation of such a bias; presumably the large threes attract the smaller fours to their shoals — in which case the increments should have been reduced. To obtain increased increments only the larger fours could have been sampled and the smaller fours must have been overlooked. We do not understand how evidence might be provided for such a speculation. Again, it is said that in the data from Boulogne and Ostend, shown in Figure 2.3 (CUSHING and BURD, 1957), the growth increments did not increase. The figures are: —

	1950/51		
	3/4 cm	4/5 cm	5/6 cm
East Anglia	1·9	1·6	1·1
Boulogne	2·2	1·4	0·9
Ostend	1·5	1·5	0·8
Average increment at East Anglia, excluding 1951	1·5	1·0	0·7

BURD's Figure 20 (1954), which shows the mean length at Shields from 1946–53, is said to resemble the length distribution on the Fladen Ground given in CUSHING and BURD (Figure 2.4). We agree that there is a resemblance, but would point out that as there is a difference of about 2 cm in all observations we would limit our agreement to mere "resemblance".

HODGSON expects that the mean length from April to September in the Shields fishery should show the increase in length in 1950 because this fishery is not far from Flamborough. But this is unlikely as recruits keep entering the fishery in maturity stages I and I–III all through the summer. Also the Shields fishery is a mixed one having spents in the early period and, later, maturing fish of both Bank and Downs stocks (BURD, 1956, 1958). Hence an overall mean from this mixed fishery cannot be a good measure for showing variations in growth from year to year, particularly as the increase in mean length in 1950 was limited to the Downs stock. The fish of 4, 5, and 6 years of age in the northern North Sea in 1950 were smaller than those of 1949 and the increase from 3 to 4 in 1949–50 was less than 1 mm (CUSHING and BURD, 1957, Fig. 2.4).

2. Advance in Maturity

In our discussion of l_1 distributions, HODGSON asks why in 1952, the l_1s of the three year-olds were smaller than those of 1948 and 1949, before increased growth became effective. The answer is that under partial recruitment, only the large fish of the year-class come in at three years of age, the fish with the large l_1s. Now, under full recruitment, all the fish come, which means that those with the small l_1s come too. We believe that the small threes in 1952 entered the fishery, under full recruitment, whereas HODGSON believes that they

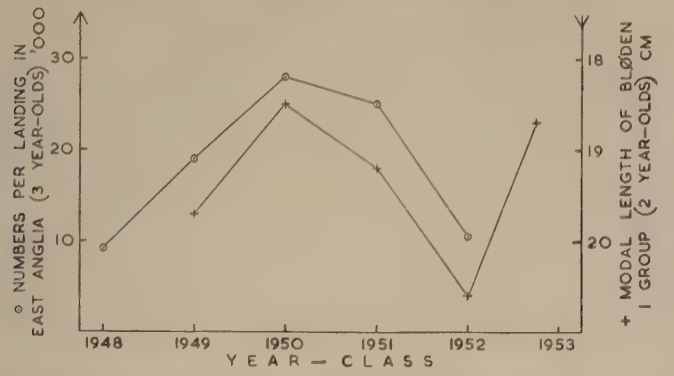

Figure 1. The relation between modal length on the Bløden Ground and the numbers of recruiting three year-olds to East Anglia.

were caught on the Bløden Ground and did not reach East Anglia. So on his hypothesis, the l_1 of the threes in 1952 should be high and on ours it should be low — as it is. Thus, we do not think that the phenomenon described could equally well have been produced by interference with the four year-old recruits.

The real point of HODGSON's criticism, however, which does not emerge from his text very clearly, is that the 1949 year-class did not grow more, as did the 1950 year-class and its successors, for the 1949 year-class lived its first year in 1950. We said quite clearly that the threes increased in size in 1950 and that older fish did so in 1951; further, we said that the l_1 increased in size at the same time as the older fish, that is, *fish older than three*.

HODGSON does not appear to understand the forecast of three year-old recruits to East Anglia which was made from the Bløden Ground data by Mr. POPP MADSEN. This is because it is assumed that the three year-old recruits do not live on the Bløden Ground, but north-west of the Dogger (HODGSON, 1957). BERTELSEN and POPP MADSEN (1953, 1954, and 1955) have distinguished between early and late autumn spawners in the l_1 distributions on the Bløden Ground. As there is a marked relation between l_1 and total length, the same separation can be made in the total length distributions. POPP MADSEN's forecast relates numbers of East Anglian recruits to the modal length on the Bløden Ground; for example, if the modal length is low, East Anglian recruitment will be high and vice versa. The correlation between the two variables is quite good (Fig. 1) and does imply that the three year-old recruits do come from the Bløden Ground; hence, they have been subject to fishing there and despite this, the numbers of three year-old recruits have remained high since 1952. This, to our minds, damages HODGSON's hypothesis on the mechanism of recruitment (HODGSON, 1957).

HODGSON points out that in our Figure 2.6 (CUSHING and BURD, 1957), which shows the average age distribution for 1924–27, there is only one year-class, the 1920, which reaches its peak at five years of age and that this is the only one of the whole series. HODGSON's Figure 2 gives the reason why we grouped the 1924–27 age distributions; the distributions of 1924, 25, 26, and 27 all peak at five or six years of age and we suspected that the year-classes before 1920 were

recruiting late. This suspicion was confirmed in the calculations for Figure 2.7 (CUSHING and BURD, 1957) — that in 1924 and 1925 the true recruitment at three was very small.

Let us suppose, however, that HODGSON is right and that the number of fours in 1925 is underestimated as he suggested. If the number of 3 year-old recruits of the same year-class in 1924 are as shown in Figure 1.4 (CUSHING and BURD, 1957), then the proportion of 4 and 5 year-old recruits would be the same as shown in Figure 2.7. But if in 1925 the number of 4 year-old recruits is greater than indicated, then the proportion of 3 year-old recruits in Figure 2.7 is too high. Thus, the main pattern of Figure 2.7, that the change in recruitment has been a slow one ever since 1924, is enhanced by the suggestion that the number of fours in 1925 was underestimated; we would point out that our Figure 2.7 shows some recruitment at five years old taking place in nearly all years up to 1953.

3. Mortality Rates

We agree with much of what HODGSON says about the variability of mortality rates; however, he says that certain values are doubtful, but gives no reason unless it be that they are high. Our best answer is to quote what we said (CUSHING and BURD, 1957, p. 26) "it is thought that the values between 5 and 7 years of age represent the best estimates, because recruitment is complete by five years old in all years and numbers of fish older than seven are subject to large sampling error and are perhaps biased by mesh selection. Allowing in Table 7 for the supposed sampling irregularity in the 5/6 group, (a negative mortality in 1935–6) it is seen that mortalities from 1950-5 are greater than from 1946–9 and about the same for pre-war years.

Turning now to the very recent years, since trawling in the Channel greatly increased from 1951, the average mortalities of 5/6 and 6/7 increase to 0·81 in the years 1952–5".

Since that was written, a much fuller investigation of the relation between mortality and effort has been carried out (CUSHING, this volume, p. 286). We find that the trends in mortality shown in Table 7 of our paper are confirmed; indeed, the same trends can be shown in Catch, in Effort, and in Fishing Mortality.

The real difference between ourselves and HODGSON is that we placed more reliance upon mortality rates than upon catch figures. So long as natural mortality is constant (which was a reasonable first assumption), increases in total mortality are proportional to increases in fishing effort. But the relation of yield on fishing effort is curvilinear to an asymptote in yield, so a large increase in effort and mortality can take place with only a small increase in yield. HODGSON compares the pre-war catches with those of 1951–55 and says: "whatever their calculations of mortality coefficients may show, there was no failure of the November fishery in 1935-38, from which we may conclude that the events of the two periods were not similar". Because we relied in the main on the mortality coefficients, we reply that there was high mortality during the one period when the November fishery failed. We would add that the estimates of catch which he quotes from our paper were underestimates because we now include one quarter of the Dogger catch (CUSHING, 1959).

4. Hodgson's Hypothesis on the Effect of the Industrial Fishery on East Anglian Recruitment

By comparing the catch/effort of the four year-olds in 1946–50, with those in 1951–55, HODGSON arrives at a percentage reduction of 37%, due to the industrial fishery. If a similar comparison is made with more samples, the following results are obtained: —

1946–50/1951–55	37%	(HODGSON's estimate)
1935–50/1951–55	23%	
1924–50/1951–55	14%	

(The last estimate was made by correcting crans/landing to numbers/landing [in thousands], by multiplying by 1·44, which is the ratio of thousands of four year-olds/landing to crans of four year-olds/landing from 1935–38.)

The two latter figures based on a greater range of data are within the ranges estimated by two other methods. CUSHING (1959) estimated the loss due to the industrial fishery to be from 15–25%; in this method, the industrial catch, reduced by two years' natural mortality was expressed as a percentage of the reduced industrial catch and the number of recruits to the Southern Bight stocks. The second method is that of the ICES tagging experiment, which showed that a fishing rate of 14% was to be expected in the autumn fishery when the catch was 70,000 tons.

HODGSON and ourselves have been opposed in controversy on the effect of the industrial fishery on East Anglian recruitment. Perhaps it may be concluded from these figures that we are really in agreement and that there is no need for the controversy to continue.

Summary

In reply to HODGSON's (1958) criticisms, certain points in CUSHING and BURD (1957) have been amplified. The average numbers of *Calanus*/m^3 per month have been grouped in three periods, 1935–38, 1947–49, and 1950–54, showing that the average numbers doubled in the last period. The increments from 3/4, 4/5, and 5/6 for 1950–51 off Boulogne and off Ostend have been added to those off East Anglia, showing the same sharp difference in increment from other pairs of years.

On the maturity change, our argument on the change in l_1 has been clarified. Comparing the l_1s of the four year-old fish, about which there is no argument, it can be shown that an increase in l_1 of the four year-olds took place in 1953, the 1950 year-class; those of the 1949 year-class are as small as those of the 1946 year-class.

On the pattern of recruitment in 1924–27, we have accepted HODGSON's suggestions that the four year-old fish of 1925 were poorly represented and we find that as a consequence, the recruitment at three years of age must have been even less in 1925 than we had calculated. This, of course, strengthens our argument that the pattern of recruitment has been changing for a long time.

HODGSON's estimate of the effect of the industrial fishery is derived by estimating the reduction in four year-olds from 1946–50 with those from 1951–55. It is assumed in the method that mortality is constant during the period. It was shown that similar comparisons with a greater range of data give much lower estimates.

References

Bertelsen, E., & Popp Madsen, K., 1953. "Young herring from the Bløden Ground area". Ann. Biol., Copenhague, **9**: 179–80.

Bertelsen, E., & Popp Madsen, K., 1954. "Young herring from the Bløden Ground area". Ann. Biol., Copenhague, **10**: 155–56.

Bertelsen, E., & Popp Madsen, K., 1956. "Young herring from the Bløden Ground area". Ann. Biol., Copenhague, **11**: 125–27.

Burd, A. C., 1954. "North Shields fishery, 1947–53". Ann. Biol., Copenhague, **10**: 166–68.

Burd, A. C., 1958. "The North Shields fishery 1949–1955". Rapp. Cons. Explor. Mer, **143** (2): 124. (Summary.)

Burd, A. C., 1958. "Recruitment and the North Shields fishery". ICES, Herring Committee, Paper No. 67.

Cushing, D. H., 1959. "The effect of fishing on the herring of the southern North Sea". J. Cons. int. Explor. Mer, **24**: 283–307.

Cushing, D. H., & Burd, A. C., 1957. "On the herring of the southern North Sea". Fish. Invest., Lond., Ser. 2, **20** (11).

Hodgson, W. C., 1958. "On the interpretation of the East Anglian herring data 1923–1955". J. Cons. int. Explor. Mer, **23**: 381–89.

On the Effect of Fishing on the Herring of the Southern North Sea

By

D. H. Cushing

Fisheries Laboratory, Lowestof

I. Introduction

Since the winter of 1952–53, the East Anglian fishery has declined; the fishery in November has disappeared because of the reduction in numbers of the older fish (CUSHING and BURD, 1957). By 1956, a year in which recruitment was high, the catches of all countries on the Channel and Sandettié grounds had been reduced by one-third as compared with 1955 and by half to two-thirds as compared with 1954; the Belgian spent-herring fishery did not take place.

The present paper has several aims: firstly, to define the area where fishing effort bears effectively on the Downs stock; secondly, to investigate the possibility of a change in natural mortality since 1950–51; thirdly, to estimate the effect of the industrial fishery for immature fish on recruitment to the adult fisheries; and lastly the nature of the changes in yield in recent years is described.

In the adult fisheries from 1950–55, mortality rates increased more quickly than did the estimated effort. Hence the possibility of natural changes was raised. It will be shown that in East Anglia, an increase in fishing efficiency took place; as the estimated effort in the Southern Bight was based on East Anglian effort, some true increase in effort was masked by the increase in efficiency in the East Anglian fishery. Again it will be shown that the trends of catches in the Southern Bight since before the war roughly follow the trends in apparent fishing mortality. Thus, from the estimates given, it will be confirmed that the reduction of the fisheries in the southern North Sea is due to an increase in fishing activity.

Before the question of mortality and effort is dealt with, the mortality rates themselves should be presented in full detail, as follows in Section II.

II. The Variability of Mortality Rates

Samples of fish have been examined for age in the East Anglian fishery since 1924. Since 1935 the numbers of each age-group have been estimated as number/landing (or numbers per arrival) (see HODGSON, 1939, for the detailed procedure). Table 1 shows a series of mortality rates for ten years before the

war and a further series for nine years after the war; the pre-war set was calculated from the percentage age distributions raised by the average catch per effort and the post-war set was estimated by HODGSON's later sampling procedure.

Mortality rates have not been estimated from the pair of ages 4/5 because in the early years it is likely that some recruitment took place even in the fifth year of life. Since 1946, mortality rates from the age pair 4/5 may be free from error due to recruitment; since 1950–51, they are almost certainly free from that error, because of the advance in maturity which took place in that period.

Table 1

Mortality rates in the East Anglian fishery, 1928–55

	5/6	6/7	7/8	8/9	Mean 5–9
1928/29	0	0·14	0·19	0·69	0·26
1929/30	0·65	0·43	0·37	0·98	0·61
1930/31	1·07	0·62	0·63	0·49	0·70
1931/32	0·81	0·41	0·74	0·98	0·74
1932/33	0·32	0·59	0·13	0·64	0·42
1933/34	0·24	−0·08	0·47	0·34	0·24
1934/35	0·61	0·69	0·94	0·36	0·65
1935/36	−0·46	0·21	0·51	0·21	0·12
1936/37	0·52	0·75	0·92	0·59	0·70
1937/38	0·71	0·95	−0.11	0·62	0·54
Mean	0·48	0·47	0·48	0·59	

	4/5	5/6	6/7	7/8	8/9	Mean (5–9)	Mean (5–7)
1946/47	0·33	0·63	0·18	0·90	0·89	0·65	0·40
1947/48	0·38	0·13	−0·39	0·46	0·11	0·08	−0·13
1948/49	0·28	0·45	0·59	1·64	1·48	1·04	0·52
1949/50	0·60	0·48	0·50	0·69	0·33	0·50	0·49
1950/51	0·31	0·53	0·57	0·48	0·62	0·55	0·55
1951/52	0·46	0·32	0·52	0·69	0·56	0·52	0·42
1952/53	0·83	1·06	1·12	1·04	0·80	1·01	1·09
1953/54	0·39	0·36	0·07	0·45	0·18	0·27	0·21
1954/55	1·38	1·09	1·13	1·22	1·44	1·22	1·11
Mean	–	0·56	0·48	0·84	0·71		

An analysis of variance was carried out, for the ages 5–9, as presented in Table 2.

Table 2

Analysis of variance of East Anglian mortality rates 1928–38 and 1946–55

1928–38	Degrees of freedom	Mean square
Between Years	9	0·20 (p = 0·05)
Between Ages	3	0·04
Residual.....	27	0·09
1946–55		
Between Years	8	0·56 (p = 0·01)
Between Ages	3	0·24 (p = 0·05)
Residual.....	24	0·06

From the two analyses and from Table 1, the following conclusions may be drawn: —

A. Mortality appears to increase slightly with age. There are high apparent mortality rates for the 7/8 and 8/9 age pairs in 1948–49, which are possibly not reliable because they are much higher than the rates for other ages in the same years. If the mortality rates of the ages 7–9 in the years 1948–49 are ignored, the regression of mortality rate on age is slight.
B. The mean square for "Between Years" is greater than that for "Between Ages" and also greater than the residual mean square. Hence the variance due to sampling the catches, which is that estimated by the residual mean square, is less than the variances due to true changes in mortality and to other sources of variance, for example, vulnerability. Indeed, during the period 1946–55, there are significant differences "Between Ages" as well as "Between Years". This may be due to the high values in 1948–49 mentioned above.

The residual variance was further analysed in different age-groups by estimating the variance of deviations from the annual mean of age pairs. The variances for each of the four age pairs in the two periods were as follows: —

	5/6	6/7	7/8	8/9
1928–38.....	0·066	0·051	0·101	0·057
1946–55.....	0·044	0·040	0·042	0·044

The variance for each age-group is small and there is no trend of variance with age (or inversely with the size of sample). It follows that all estimates of mortality are equally precise and that they should be given equal weight. It will be noticed that the variance is less during the period 1946–55 than in the period 1928–38; as this variance is mainly one of sampling the catches, the method used in 1946–55 (Hodgson, 1939) is more efficient than that used in the earlier period.

Since 1952, it is likely that full recruitment has taken place at three years of age (Cushing and Burd, 1957) and so the mortality rates from three to four and from four to five may be used. Since 1954, the numbers of older fish have decreased to such an extent that it is possible that they are not being sampled properly. Before this date, mortality rates did not increase much with age; since 1954, mortality rates of older fish have increased with no increase of effort, independently of the mortality rates of younger fish.

This sampling problem may be partly overcome by accepting only those estimates of numbers of an age-group which comprise more than five per cent. of the estimate of numbers of all age-groups. Using this convention, it is found that: —

(1) in 1952 and 1953, estimates of both 8 and 9 year-olds should be excluded;
(2) in 1954, 55, and 56, all estimates from six to nine are excluded;
(3) in 1957, all estimates from five to nine are excluded.

Taking into account both the recruitment change and the poor sampling of the older age-groups since 1954, Table 3 gives the mortality rates since 1952. In the sections which follow, average mortality rates are used as follows: —

1928–48.....	5–9	1950–52.....	5–9
1948–50.....	5–7	1952–57.....	as in Table 3

Table 3

Mortality rates from 1952–57

	3/4	4/5	5/6	6/7	Mean
1952/53	0·57	0·83	1·06	1·12	0·89
1953/54	0·41	0·39	–	–	0·40
1954/55	1·12	1·39	1·09	–	1·20
1955/56	0·63	0·74	–	–	0·69
1956/57	1·09	–	–	–	1·09

In the period 1948–50, the very high mortality rates for the ages seven to nine have been excluded firstly, because they are much higher than those on the younger and more abundant age-groups and secondly, because although effort was increasing at this time, the increase was not great.

III. The Relation between Mortality and Effort

A measure of effort was used in CUSHING and BURD (1957) by which the East Anglian effort as number of arrivals was raised by the ratio of the Southern Bight catch to the East Anglian catch. This measure must now be slightly corrected because the number of arrivals (or landings) is not necessarily the number of shots, because it takes no account of the number of shots made when the catches are so small that it is not considered worth while steaming back to port. Fortunately, "overdays" or "days, iced" are recorded in the collector's books, and so a factor for this effect can be estimated. Using all the post-war material and two collector's books from the pre-war period, a factor of 1·24 was obtained for converting "landings" into "shots". There was no difference between the pre-war and post-war observations and there was no trend in the very recent years. By "East Anglian effort" is now meant the number of landings recorded in CUSHING and BURD (1957), on p. 22, raised by 1·24.

The Southern Bight fisheries which work on the Downs stock (CUSHING and BURD, 1957) include the East Anglian drift-net fishery with its Dutch and German partners, the Channel trawl fishery, and the Belgian spent-herring fishery; but the northern limit of the Downs stock is not well defined. From marking experiments (particularly the Scottish ones in the northern North Sea; WOOD, PARRISH, and MCPHERSON, 1955) and from echo-surveys across the approaches to the East Anglian fishery (TUNGATE, 1958), it is probable that the Downs herring feed in the region north of the Dogger. An attempt will be made to separate the components of the Bank and Downs stocks on the Dogger.

Since 1950, the English research vessels have made nearly 100 hauls in the Dogger area in September and October. The maturity stages of the fish caught may be grouped: —

A	B	C
I–I·III	III–IV·V	V–VII and II·III

Group A are immatures from the eastern nursery ground; group B are probably Downs fish on their way south to spawn in the Straits of Dover and group C are Dogger spawners. The proportion by numbers of group B to group

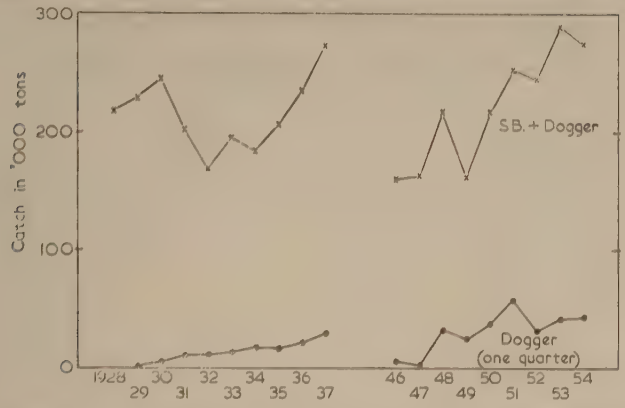

Figure 1. Catches from the Downs stock of herring in the Southern Bight and on the Dogger from 1928–55.

C was 1:3, hence it is likely that one quarter of the Dogger catches of adult fish was composed of Downs fish. Figure 1 shows the catches on the Dogger from 1928–54, reduced to one quarter, and the total catches from 1928–54 from the Southern Bight with one quarter of the Dogger catches added. High levels of catch occurred on the Dogger in 1936–37 and from 1947 onwards, and consequently the catches from the "Southern Bight and Dogger" group were higher in 1951–54 than during any four years previously. Yet this must be an underestimate because no catches north of the Dogger can yet be included.

The effort on the Downs stock in the southern North Sea may be calculated in two ways: — (1) The East Anglian effort, as the number of drifter shots, is raised by the ratio of the total catch from the Downs stock in the Southern Bight and on the Dogger, to the East Anglian catch (Col. (a) in Table 4). (2) The effort in each fishery as the number of "fishing days" is added to give an estimate of total effort; the standard "fishing day" used was that of a German trawler, which is roughly three times as effective as a drifter and the estimates of effort for each gear are corrected by factors to bring them to the standard (Col. (c) in Table 4). The two estimates are independent and the second makes use of more information, but could be biased if the gear factors are themselves biased. The quality of the first estimate depends upon the information from the fishery on which the ratio is based; for the East Anglian fishery, the evidence from echo-survey and catch distributions in area, shows that the stock is in the main adequately sampled in area.

Table 4 shows the effort as calculated from 1928–56 using the first method and from 1946–56, using the second method. It was impossible to apply the second method to the pre-war statistics because they have not been presented in a sufficiently detailed manner. The purpose of the comparison is to show that effort as calculated by the first method is reliable.

In the same table are given the catches from the Southern Bight and Dogger; it will be noticed that although the pre-war catches (1928–37) are lower than those from 1950–55, yet the effort in the latter period is on average less than

Table 4

The estimated effort exerted on the Downs stock, on the Dogger, and in the Southern Bight

	(a) By raising English effort, in drifter shots, by the ratio of the Downs catch to the English catch	(b) Column (a) corrected by the efficiency factor (efficient drifter shots)**	(c) The total number of fishing days (as made by German trawlers)	(d) Total catch in metric tons
1928	36,490	36,490		218,000
1929	39,460	39,460		229,000
1930	46,990	46,990		245,000
1931	50,530	50,530		202,000
1932	49,780	49,780		169,000
1933	48,230	48,230		195,000
1934	39,510	39,510		184,000
1935	38,940	38,940		206,000
1936	47,840	47,840		236,000
1937	49,940	49,940		274,000
1946	20,950	15,920	5,464	160,000
1947	21,770	23,080	9,630	163,000
1948	29,450	36,230	12,515	217,000
1949	22,080	31,140	9,191	162,000
1950	30,150	44,330	11,738	217,000
1951	38,210	56,180	12,726	253,000
1952	36,880	54,220	14,172	245,000
1953	47,090	69,220	15,191	290,000
1954	38,120	56,040	13,452	275,000
1955	35,289	45,880	12,925	145,000
1956	22,010*	28,610*	7,042*	82,038*

* From the *Statistical News Letters* of ICES, in which the French statistics are not included: hence the figures are underestimated by perhaps one-fifth.

** From *Bulletin Statistique, Jahresberichten der Deutschen Fischereien*, Rapp. Cons. Explor. Mer., **144**, and CUSHING and BURD (1957).

in the former. At the same time the average mortality rates in the East Anglian fishery taken from Table 1 were: —

1930–33	1936–38	1946–50	1951–55	1951–57
0·61	0·61	0·32	0·75	0·80

Thus, as catches increased as compared with pre-war, so did mortality, yet the effort was lower. Therefore it is possible that the efficiency of fishing increased during the period.

An attempt was made to trace a change in the relation between mortality and effort (Column (a) of Table 4) by using SILLIMAN's method (1943) for a series of short periods. Since 1928, the following periods may be distinguished: —

	Period	Z	g
I	1928–29	0·44	37,975
II	1930–37	0·51	46,470
III	1946–49	0·43	23,562
IV	1950–54	0·71	38,082

(Note: dates given cover the periods of effort.)

$$Z_A = g_A \times q + M \quad \ldots\ldots (1)$$

$$Z_B = g_B \times q + M \quad \ldots\ldots (2)$$

where M is the instantaneous coefficient of natural mortality, q is the coefficient of fishing efficiency, Z is the total instantaneous mortality coefficient, (averaged from Table 1) and g is effort averaged for the Southern Bight and the Dogger.

$$q = \frac{Z_B - Z_A}{g_B - g_A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Substituting q in (1), from three comparisons, the estimates of M and q are: —

		M	q
II/I.....	1928–39	0·17	$0{\cdot}81 \times 10^{-5}$
II/III	1930–49	0·13	$0{\cdot}85 \times 10^{-5}$
III/IV.....	1946–54	—0·03	$1{\cdot}93 \times 10^{-5}$

Using the period 1928–49, the estimates of M and q are consistent; when the later period is employed, meaningless results are obtained. This could be due to an increase in q, the coefficient of fishing efficiency, or to an increase in M, the instantaneous coefficient of natural mortality, or both; the possibilities cannot be distinguished.

An independent method of estimating fishing efficiency was derived in the following way. Since 1935, the East Anglian statistics have been plotted in small squares (each is $\frac{1}{9}$ of a statistical square) by three-day periods; for each three-day period, it is possible to obtain the sum of catches and the sum of catches/effort. From these figures the effective overall fishing intensity may be found for each three-day period or for the season. The effective overall fishing intensity, f, is defined: —

$$f = \sum C_{ij} \Big/ \sum (C/g)_{ij}$$

where C is the catch in square i in period j, where C/g is catch/effort in square i in period j (Beverton and Holt, 1957).

If the value of f for any one season is divided by the number of landings or the number of shots, a measure of the relative efficiency of fishing is obtained. Since 1935 it can be shown that this estimate of efficiency has increased by about 20%. The estimate of efficiency used in this way is defined by: —

$$f \times \frac{\text{n} \cdot \text{squares}}{\text{n} \cdot \text{shots}}$$

The number of squares comes into the estimate because fishing intensity is defined as fishing effort per unit area, or statistical square.

There is another effect to be considered: the fleet has decreased in numbers since 1935 and so the number of squares sampled has become reduced. In other words it is possible that in 1935 the stock was more extensively sampled than in 1955. To correct for this, the following method (derived by my colleague, J. A. Gulland) was used: — 1936 was used as a standard year and comparing the fleet area in that year with any other year, there is a common area.

Let f in the common area be a;
let f in the rest of the fished area in 1936 be b;
let the stock (as the sum of catches/unit effort) in the common area be A;
let the stock in the rest of the fished area in 1936 be B.

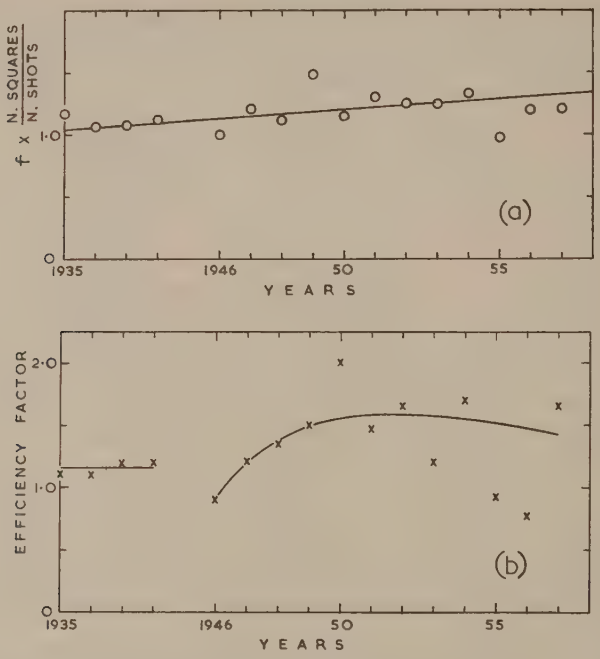

Figure 2. The increase of efficiency in the East Anglian drift-net fishery.
(a) The estimated fishing intensity dividing by the number of shots per square. – The crude efficiency factor from 1935–57.
(b) The efficiency factor corrected for the change in fleet area from 1935–57. From 1954–57 the line to the points is drawn a little too high.

Then for 1936, f is $\dfrac{(A \times a) + (B \times b)}{A + B}$

In any other year we have A', B', a' and b'; it is assumed that $\dfrac{B'}{A'} = \dfrac{B}{A}$ and so $\dfrac{(A' \times a') + (B' \times b')}{A' + B'}$ is calculable.

Such estimates based on the standard year 1936 and divided by the number of shots are corrected estimates of fishing efficiency.

Figure 2 shows the increase of efficiency from 1935–57, firstly (2a) as $f \times$ n. squares/n. shots and secondly (2b), the estimate of intensity corrected for the change in fleet area and then divided by the number of shots. It will be seen that there has been an increase in the efficiency of the drift-net as used in the East Anglian fishery since before the war. It is impossible to find the cause of this change, but it is likely to be due to one of three factors, echo-sounding, radio, or the greater sea room available to a smaller fleet; all three possible factors may be included in the more general term, searching. As the drift-net has not changed structurally during the period, an increase in efficiency must be due to improved searching, in one way or another. The line drawn to the points in Figure 2 (b) is too high in 1954–57; this means that the efficiency factor for 1954 is slightly overestimated. Consequently effort is overestimated by about

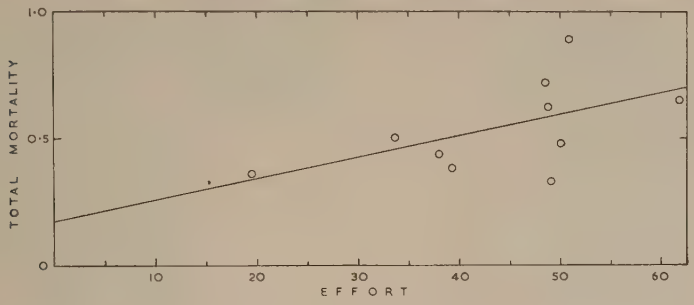

Figure 3. The regression of total mortality on effort from 1928–55.

5% in that year. This error makes no noticeable difference to the regression of Z on g from 1928–55 shown in Figure 3.

The test given by SILLIMAN's method above may now be completed with the efficiency factor taken into account: —

		M	q
II/I.....	1928–39	0·17	$0{\cdot}81 \times 10^{-5}$
II/III	1930–49	0·13	$0{\cdot}85 \times 10^{-5}$
III/IV.....	1946–54	0·18	$0{\cdot}95 \times 10^{-5}$

The estimates of M, the natural mortality, are reasonably consistent and the estimates of q, the coefficient of efficiency of fishing, show an increase over the period, of much the same order as that calculated independently. The reason for using SILLIMAN's method in short periods was to detect any change in M or q between 1928 and 1954, to find whether the regression of mortality on effort was curvilinear. The test lies in the consistency of estimates and not in the chance of their being significantly different. Thus it was the values of M and q in 1946–54 being so different from the estimates for 1928–49 that led to the discovery of a change in efficiency.

Figure 3 shows the regression of total mortality Z on effort, corrected for efficiency. The regression is not significant (the probability that the slope is different from zero is 0·1); the estimate of natural mortality is approximately 0·2. The regression includes all points from 1928–55 and they have been grouped in pairs in order to try to overcome changes in vulnerability. Vulnerability has been defined as the coefficient relating catch per unit of effort to abundance; for a given year-class, under conditions of constant mortality, an excessive catch per unit of effort in one year is countered by a reduced catch per unit of effort in the next year. In the first year, when the stock was excessively vulnerable to the gear, more fish were caught and the catch per unit of effort was high; consequently, abundance became reduced and in the next year, the catch per unit of effort was reduced. Thus, changes in vulnerability can be dealt with by pairing observations from successive years.

The period of high effort is from 1951–54: 54,220 to 69,220 drifter shots, which corresponds to a total mortality of 0·63–0·77. With a natural mortality of 0·17, we have a fishing mortality from 1951–54 of 0·46–0·60. The estimates made in this way are not of high quality because of the variability of the mortality rates. The estimate of effort is necessarily a minimal one because that exerted on the Downs stock in the feeding fisheries north of the Dogger cannot yet be

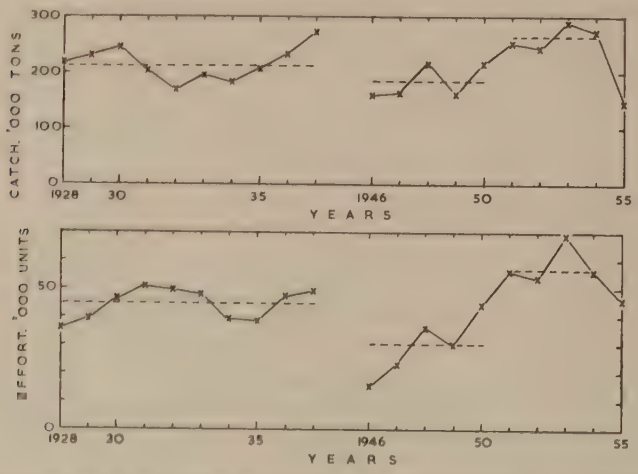

Figure 4. Catches of and effort on the Downs stock of herring in the Southern Bight and on the Dogger from 1928–55.

separated from that exerted on the Bank stock. Nevertheless, it is likely that the fishing mortality for the period 1951 54 was somewhat more than three times the natural mortality, averaged from 1928–55.

It might be possible that the older fish emigrated to the north after 1951; such an effect should be shown as a change in M or q in the use of SILLIMAN's method for short periods and should be accompanied by a drop in catches, if recruitment were constant. Recruitment was constant, catches increased and no change in M or q was detected. Hence, it is unlikely that emigration of the older fish took place.

The same point may be made in a simpler manner by comparing the catches with the effort since 1928 (Fig. 4). Three periods may be separated, 1928–37, 1946 50, and 1951 54 (the year 1938 is not used because satisfactory catch figures for that year cannot be elicited from all countries). It is clear that during the period 1951 54 both catch and effort are higher than at any other time. Hence, it is not surprising that mortality should have increased in 1951–54 and that the numbers of older fish should have been reduced.

If the period 1928 55 is divided into three sub-periods, 1928–38, 1946–50, and 1951 55, effort, catch, and fishing mortality may be compared: —

	1928–38	1946–50	1951–55
M	0·17	0·17	0·17
F	0·33	0·27	0·54
effort (efficient drifter shots)*	44,170	30,140	57,000
Catch (metric tons)	216,000	184,000	242,000

* From Col. (b) in Table 4.

Thus, the trends in catches are the same as those in F, the fishing mortality coefficient, and in effort; if the recent mortalities were due to emigration, the catches would have been reduced.

In 1955, 1956, and 1957, the numbers of older fish have become further reduced and the mortalities have remained high. The cause of the high mortalities is partly due to the poor sampling of older fish referred to above, but in 1955 the catch was nearly halved, yet the mortality on the three to four year and four to five year pairs (1955–56) remained high (0·69). It will be noticed from Figure 4 that the effort in 1955 remained as high as pre-war and so taking the regression in Figure 2 a total mortality of 0·55 would have been expected in any case.

By 1956 effort had dropped to about 20,000–25,000 drifter shots, using the method of raising the East Anglian effort by the ratio of the Southern Bight catch to the East Anglian catch; estimated as "catching days", it had fallen to about 7,000. The mortality rate at East Anglia of the three to four year pair was greater than that expected by the effort exerted. This is a single observation which may be influenced by a vulnerability effect; in the week of the full moon in November 1957, there was a strong gale which kept the fleet in port for four days and which may have dispersed the fish, giving an underestimate of four year-olds (as well as three year-olds).

With the use of rather rough methods and in the face of exceedingly variable material, we tend to conclude that the recent increases in mortality in the southern North Sea are associated with increases in fishing effort. It is thought that the peak of effort was reached in 1953 and that the true fishing effort has declined slowly till 1955 and then sharply in 1956; until 1956, it is likely that fishing mortality remained as high as 0·50. By 1957, it is likely that fishing mortality dropped below this level.

IV. The Effect of the Industrial Fisheries for Immature Herring on Recruitment to the East Anglian Fishery

In August 1957 ICES started a tagging experiment in the industrial fishery for immature herring, east of the Dogger Bank. The primary purpose of this experiment was to determine the fishing mortality by the recovery of internal tags from the fish meal factories. A secondary purpose was to give some idea of the directions of migration away from the nursery grounds into the adult fisheries by the recovery of externally tagged fish over a long period.

The processing of the data may be a little complicated and it was thought worthwhile attacking the problem from another direction, partly to give the order of result expected, as a check, and partly to make some sort of framework into which the results of this international experiment may be fitted. The method used will also give an opportunity of making a check on Hodgson's (1956) hypothesis.

The industrial fishery on the eastern nursery ground in the North Sea has yielded over 100,000 tons of immature herring in each year since 1954; as these small fish run from 1500–3500 to the cran, the number of fish caught in each year since 1954 ranges from 1,500,000,000 to 2,000,000,000. By comparison, only 100,000,000 fish were caught in the East Anglian fishery in 1955 and 1956.

There are two parts to the industrial fishery, the spring fishery practised by the Danes only and the autumn fishery exploited by the Danes and Germans. There are two main age-groups in the fishery, the I group and the II group; combining the spring and autumn fisheries, 80% of the catch by weight is

composed of I-group fish and 20% of II-group fish. The autumn fishery is 5–10 times larger than the spring fishery and then the I- and II-group fish are very nearly 2 and 3 years old respectively. 0-group fish are also caught in the autumn fishery, but only in small quantities (BERTELSEN and POPP MADSEN, 1953, 1954, and 1956).

Any calculations that are made are based on the numbers of fish caught in each year-class. For this purpose, it is assumed that there are 5·5 crans/ton* and that there are 3–3500 I-group fish/cran and 1–1500 II-group fish/cran. Table 5 shows how such estimates of numbers are derived, based on the information given in the preceding paragraphs.

Table 5

The numbers of fish caught in the industrial fishery on the eastern nursery ground

	A Industrial fishery (tons)	B I group (tons)	C II group (tons)	D B × 3000 × 5·5	E C × 1000 × 5·5
1949	2,000	1,600	400	$26{\cdot}4 \times 10^6$	
1950	5,000	4,000	1,000	$66{\cdot}0 \times 10^6$	$5{\cdot}5 \times 10^6$
1951	38,000	30,400	7,600	$501{\cdot}6 \times 10^6$	$41{\cdot}8 \times 10^6$
1952	49,000	39,200	9,800	$646{\cdot}8 \times 10^6$	$53{\cdot}9 \times 10^6$
1953	75,000	60,000	15,000	$990{\cdot}0 \times 10^6$	$82{\cdot}5 \times 10^6$
1954	103,000	82,400	20,600	$1359{\cdot}6 \times 10^6$	$113{\cdot}5 \times 10^6$

By year-classes the numbers are: –

	(a)	(b)
1948	$31{\cdot}9 \times 10^6$	$39{\cdot}1 \times 10^6$
1949	$107{\cdot}8 \times 10^6$	$139{\cdot}7 \times 10^6$
1950	$555{\cdot}5 \times 10^6$	$664{\cdot}1 \times 10^6$
1951	$729{\cdot}3 \times 10^6$	$878{\cdot}4 \times 10^6$
1952	$1103{\cdot}3 \times 10^6$	$1325{\cdot}2 \times 10^6$

(a) is calculated, using factors of 3000 I-group fish/cran and 1000 II-group fish/cran.
(b) is calculated, using factors of 3500 I-group fish/cran and 1500 II-group fish/cran.

A recruitment change took place in the East Anglian fishery in 1950–51, which may be considered in two ways. Firstly, HODGSON (1956) has assumed that the four year-old recruits have never reached East Anglia because they have all been caught in the industrial fishery. Secondly, CUSHING (in CUSHING and BURD, 1957) interpreted the recruitment change as an advancement in maturity, so all recruits came into the fishery at three years of age and consequently, there were no four year-old recruits after 1950–51.

The average proportion of numbers of three year-olds to numbers of four year-olds in the subsequent year, from 1946–50, is 1:1·8. So if the number/landing of three year-olds in any year-class is multiplied by 1·8 the number/landing of four year-olds is estimated for the subsequent year. Using HODGSON's hypothesis, the difference between this quantity and the observed number of four year-olds is the estimated "loss" of four year-olds, expressed as numbers/landing. In order to estimate the total loss to the fisheries in the Southern Bight, which are dependent on the Downs stock (CUSHING and BURD, 1957),

* English long ton which approximately equals the metric ton of one thousand kilogrammes.

the calculated loss must be raised by the number of landings in East Anglia in each year and by the Southern Bight factor, which is the ratio of the Southern Bight catch to the East Anglian catch.

If the industrial catch in numbers, as calculated in Table 5, is compared with the estimated loss of four year-olds in numbers, it is found that in 1951, 1952, 1953, and 1954, the estimated loss was greater than the industrial catch: —

Year-class	Years of industrial fishery	Industrial catch in numbers, by year-classes	Estimated loss of four-year-olds in Southern Bight catch	Loss/ Catch
1948	1949/50	$31{\cdot}9 \times 10^6$	$168{\cdot}0 \times 10^6$ (1951)	5·2
1949	1950/51	$107{\cdot}8 \times 10^6$	$197{\cdot}0 \times 10^6$ (1952)	1·8
1950	1951/52	$555{\cdot}5 \times 10^6$	$777{\cdot}0 \times 10^6$ (1953)	1·4
1951	1952/53	$729{\cdot}3 \times 10^6$	$811{\cdot}0 \times 10^6$ (1954)	1·1
1952	1953/54	$1103{\cdot}3 \times 10^6$	$930{\cdot}0 \times 10^6$ (1955)	0·8

The year in brackets is the year of arrival as four year-old fish in the Southern Bight.

As the estimated losses in 1951–54 were greater than the catches in 1949–53 it is likely that the apparent loss must be due to some other cause and the first interpretation referred to above must be rejected.

We now turn to the second interpretation, that an advance in maturity in 1950–51 has since then brought all the recruits into the fishery at three years of age. Since 1952, the numbers of three year-old fish reaching East Anglia have increased greatly; the actual figures are, in numbers/landing: —

1952	19,200
1953	27,700
1954	25,200
1955	12,100
1956	26,100

These figures are two to four times greater than 5,900, which was the average number of three-year-olds from 1924–50 (Table 6 in CUSHING and BURD, 1957). If the change in recruitment is accepted as being due to an advancement in maturity in 1951–52, then the high figures since 1952 are merely due to the additional recruits that used to come in as four year-olds, but now appear as three year-olds.

There is another way of calculating the probable loss of recruits to the East Anglian fishery. By this method (which follows that of GULLAND, 1955, on immature whiting) it is assumed that the change in recruitment in 1950–51 was due to an advance in maturity and so the numbers/landing of three year-old fish caught in any one year represents an index of all the recruits in that year-class.

Let N_3 and N_4 be the numbers of three and four year-old fish in the stock, respectively,

then $$N_4 = N_3 e^{-(Z)(t_1 - t_0)},$$

where (Z) is the mortality rate from t_0 to t_1, which in this case is one year. Between t_0 and t_1, the numbers of fish dying are

$$N_3 - N_4 = N_3 - N_3 e^{-(Z)(t_1 - t_0)} = N_3 (1 - e^{-(Z)(t_1 - t_0)})$$

The fraction killed by fishing is

$$\frac{F}{Z} \times N_3 \left(1 - e^{-(Z)(t_1 - t_0)}\right) = C,$$

the catch of recruits (three year-old fish), assuming full recruitment at three years old.

Therefore

$$N_3 = \frac{C \times Z}{F\left(1 - e^{-(Z)(t_1 - t_0)}\right)}$$

the total number of fish at three years old.

If the catch of the industrial fishery has reduced N_3 the effect should be found in the following way.

If Q is the industrial catch in numbers in any year-class then

$$Q \times \varrho \times e^{-M(t_\alpha - t_\beta)} = L$$

where L is the loss to the Downs stock in numbers, ϱ is the proportion of the industrial fishery which supplied recruits to the Downs stock (necessarily less than unity), where M is the natural mortality rate of herring on the eastern nursery ground, and $t_\alpha - t_\beta$ is the time between entry to the industrial fishery, t_α, and recruitment to the East Anglian fishery, t_β.

So, without the industrial fishery, the number of fish alive at three years old would have been $N_3 + L$. Then the expression $\frac{L}{L + N_3} \times 100$ is the percentage loss to any one year-class in the Downs stock.

The calculation takes the following form for the period 1950–55 (see Figure 5).

	Z	M	Catch/landing of recruits in thousands $\times 10^3$	$N_3 \times 10^9$	$\frac{L}{\varrho} = Qe^{-M(t_\alpha - t_\beta)}$
1950	0·5	0·25	19·6	2·01	24·9
1951	0·5	0·25	13·9	1·72	84·1
1952	0·6	0·25	19·2	1·82	433·3
1953	0·6	0·25	27·7	3·36	568·9
1954	0·7	0·25	25·2	2·01	860·6
1955	0·7	0·25	10·9	1·17	1190·6

$$\frac{L}{L + N_3} \times 100$$

	$\varrho = 1$ %	$\varrho = 0{\cdot}5$ %	$\varrho = 0{\cdot}25$ %	$\varrho = 0{\cdot}10$ %
1950	1·2	0·6	0·3	0·1
1951	4·7	2·4	1·2	0·5
1952	19·2	10·6	5·6	2·3
1953	14·5	7·8	4·1	1·7
1954	30·3	17·6	9·7	4·1
1955	50·4	33·7	20·3	9·2

The values of the percentage loss depend very much upon the value of ϱ chosen, but by 1955 all are higher than the previous estimate of 6% (CUSHING and BURD, 1957). Even if ϱ were as low as 0·10, the percentage loss in 1955

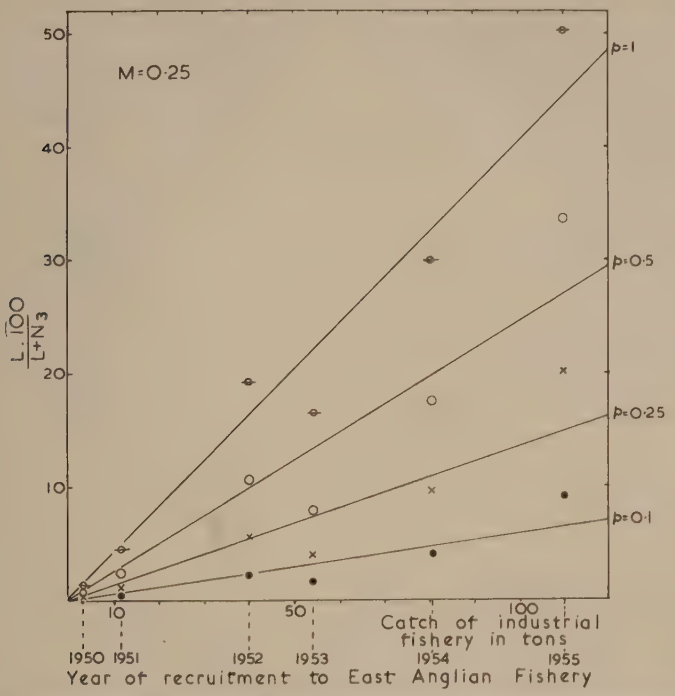

Figure 5. The estimated loss, as a percentage, to the Downs stock, due to the industrial fishery for immatures since 1950. L is the loss in numbers, N_3 is the number of recruits to the Downs stock, ϱ is the proportion of a year-class in the industrial fishery which reaches the Downs stock.

would have been nearly 10%; if ϱ were as high as 0·5, which is not improbable, the percentage loss in 1955 would have been 34%. These calculations are shown graphically in Figure 5.

The calculations given above were based on a value of $M = 0{\cdot}25$; it is possible that the value for the immature fish is higher. The percentage losses were recalculated at different levels of M, as shown in Figure 6. If M is taken to be 0·3—0·5 and ϱ as 0·25—0·5, the percentage loss in 1955 lay between 15–33%, say 25%.

Since 1952, the total loss in numbers is calculable on the following assumptions: —

	Z	F	$N_3 \times 10^9$	$\frac{L}{L+N_3} \times 100$ %	$N_3^1 \times 10^9$
1952.....	0·6	0·35	1·82	5	1·91
1953.....	0·6	0·35	3·36	10	3·70
1954.....	0·7	0·45	2·01	20	2·41
1955.....	0·7	0·45	1·17	20	1·40

where N_3^1 is the number of recruits (as stock) increased by the percentage loss

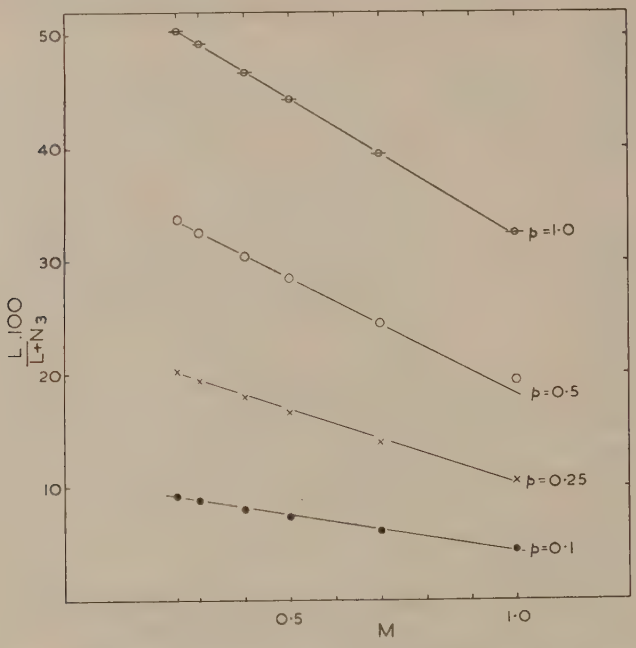

Figure 6. The relation between loss to the Downs stock and natural mortality in the industrial fishery.

estimated. So the total loss for the period 1952–55 in the Southern Bight is given by the difference between $N_3 e^{-(Z)}$ and $N_3 1 e^{(Z)}$, etc. The loss as numbers of fish (as catch of different ages) is given in the following table: —

	3	4	5	6	
1952.....	0·03	–	–	–	0·03 × 10^9
1953.....	0·09	0·01	–	–	0·10 × 10^9
1954.....	0·13	0·05	0·01	–	0·19 × 10^9
1955.....	0·08	0·07	0·03	0·006	0·186 × 10^9

The estimated loss to the Southern Bight fisheries from 1954 onwards was 0·2 × 10^9 fish, which is 4 × 10^7 fish in the East Anglian fishery or 20% of the East Anglian catch in 1954. In 1952, the year which HODGSON regarded as crucial, the estimated loss was only 2–3%.

V. The Yield of Herring in the Southern North Sea

The yield in weight is calculated from the following equation (after BEVERTON and HOLT, 1957): —

$$\frac{Yw}{R} = F \times W_\infty \times e^{-M^1(t_\varrho' - t_\varrho)3} \sum_{n=0}^{3} \frac{\Omega n e^{-nk(t_\varrho' - t_0)}}{Z + nk} (1 - e^{-(Z+nk)(t_\lambda - t_\varrho')})$$

where M^1 is the instantaneous coefficient of natural mortality in the immature phase,
M is the instantaneous coefficient of natural mortality in the adult phase,
W_∞ is the asymptotic weight of the herring,
t_0 is the age of zero weight calculated from the growth equation (it may be positive or negative),
k is the "coefficient of katabolism" or the rate at which the annual increments decrease,
t_ϱ is the age of recruitment,
t_ϱ' is the age at which the fish enter the exploited phase,
t_λ is the age at the end of the lifespan,
$\Omega_0 = +1, \Omega_1 = -3, \Omega_2 = +3, \Omega_3 = -1.$

Before the yield curves are shown, the questions of selection and growth must be considered in a little more detail. All parameters used are based on samples of drift-net caught fish and it is well known that selection by a drift-net can be sharp (HODGSON, 1933). However, the effects of selection have been ignored for the moment for the following reasons: —

A. The variation in mesh size within the East Anglian fleet is probably great enough to allow the range of sizes of the abundant age-groups to be adequately sampled. RICHARDSON (1956) has shown that there are probably three points of selection at, for example, 23, 25, and 29 cm for 36 rows/yard (his Fig. 3). This range clearly covers a number of age-groups.

B. Although the gears used in the fisheries sampled from Lowestoft, Boulogne, and Ostend are as diverse as drift-nets, bottom trawls, and pelagic trawls, there is little difference between the age distribution as sampled in the three fisheries (CUSHING and BURD, 1957). Thus, it is likely that the samples of drift-net caught fish give adequate values of the vital parameters for present purposes. Also the effect of selection on the growth pattern has been minimized by back calculating the lengths from scale measurements by proportioning. The lengths-for-age obtained in this way are sometimes well fitted by the Bertalanffy equation, for example, those of the 1947–48 brood. Those of earlier broods do not fit the equation very well; there may be two reasons. The first is that there is a wide range in spawning time, which leads to variation in L_∞, the asymptotic length in the growth equation and in W_∞ and t_0 in the yield equation. Secondly, there appears to be a real difference in k in the immature and adult phases in some broods. In this paper, the best fit to the Bertalanffy equation by least squares has been used and the parameters so obtained have been used in the yield equation.

It has been shown that since 1924, the herring in the North Sea has increased

in size (ANCELLIN, 1953; ANDERSSON, 1954; CUSHING and BURD, 1957); consequently, the growth parameters have also changed. In order to illustrate the changes in yield since 1928, three broods have been selected; the 1927–28 brood as a sample of the pre-war stock, the 1944–45 brood as a sample of the stock immediately after the war, and the 1947–48 brood as a sample of the stock after the recruitment change of 1950–51. The parameters are as follows: —

	1927–28	1944–45	1947–48
W_∞	177·5 g	201·5 g	226·3 g
t_0	−1·008	−1·43	−0·60
k	0·368	0·355	0·387
M^1	0·25	0·25	0·25
M	0·20	0·20	0·20
t_λ	10·0	10·0	10·0
t_ϱ	1·0	1·0	1·0
$t_{\varrho'}$	3·5	3·5	3·0

The yield curves are illustrated in Figure 7. They are characterized by a very flat plateau, which is far beyond the range of present fishing activity. There are marked differences between the yields of different broods; in fact, that for the 1947–48 brood has a maximum at $F = 1{\cdot}2$, which is absent from the other two. The present state is shown by the curve for the 1947–48 brood, for which the Bertalanffy equation provides a good fit to the data.

The catch/unit of fishing mortality as estimated from the yield curve for the 1947–48 brood is shown in Figure 8. Comparing this with Figure 7, it will be seen that if F were reduced from 0·6 to 0·45, the yield per recruit would be reduced from 60 to 57, a reduction of 5%; from Figure 8, a reduction from $F = 0{\cdot}6$ to $F = 0{\cdot}45$ would bring about an increase in catch/unit of fishing mortality (which is proportional to catch/unit effort) of 26%.

In the herring fishery the catch per effort is very important. Most herring fisheries in the North Sea are seasonal and mixed. The East Anglian fishery in October depends largely upon Scots fishermen who spend much of the year before October seining for white fish; French and German trawlers in November and December disperse if the herring disappear, and when they return the trawlers will gather in the Sandettié Channel from as far as the Norwegian coast. The measure on which the fishermen act is the catch/effort. If this becomes reduced too far, fishing stops. Thus, in 1955 with a poor recruit class in East Anglia, the total catch there was about 20,000 tons; in 1956, with a good recruit class, the total catch was again 20,000 tons, probably because fifty fewer boats came from Scotland, the catch/effort expected by them being too low. The Belgian spent-herring fishery did not take place in 1956–57, for the same sort of reason. The Sandettié trawl fishery in strength was reduced in 1956 to a period of ten days for the same type of reason, although some sporadic fishing continued for a longer period.

The fact that the fleets tend to stop fishing for herring rather readily means that there is a limiting catch/effort. The short history of the fishery in the autumn of 1956 shows that the value of the limiting catch/effort is roughly the same for a number of European countries, despite differences in economic and social structure. From the study of mortality rates, it is possible that in 1954–55, $F = 0{\cdot}55-0{\cdot}60$; let us suppose that in 1955–56, F reached 0·60, to which corresponded limiting catches/effort in the fleets of many European countries.

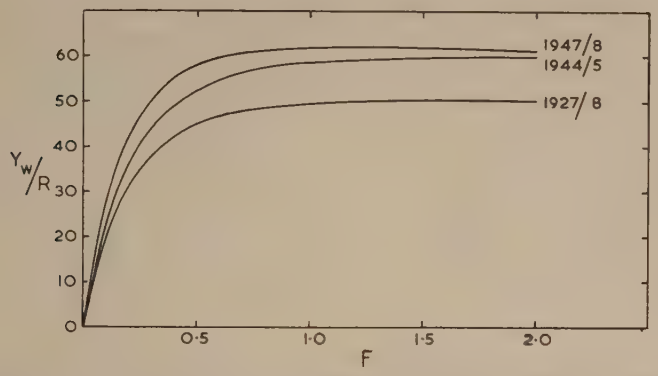

Figure 7. The yield of herring; Y/R is yield per recruit and F is fishing mortality. The yield for three broods is shown, as shown by year of birth.

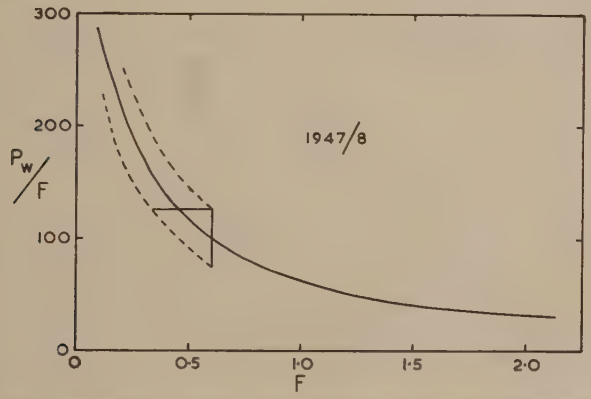

Figure 8. The catch per unit of fishing mortality (P_w/F) at different levels of F for the 1947–48 brood. The dotted lines show the coefficient of variation of catch per unit of fishing mortality due to variations in recruitment.

Just as there appears to be a limiting catch/effort at which effort decreases, so there must be a corresponding value at which effort increases. Hence, there will be an oscillation in yield and in catch/effort in place of the steady state which fishermen and their markets would prefer. Such an oscillation in yield can be described with the use of equation (8·19) in Beverton and Holt (1957).

Two types of oscillation are shown in Figure 9. The first 9 (i) is a regular and sharp one. In three years fishing mortality, F, was reduced from 0·6 to 0·45 and then it was raised again to 0·6 in the subsequent three years (Figure 9 (i) a). The yield decreased as fishing mortality decreased in the first three years; this is because fishing mortality is proportional to fishing effort. When the effort, and consequently the mortality, increased from the fourth year to the sixth year,

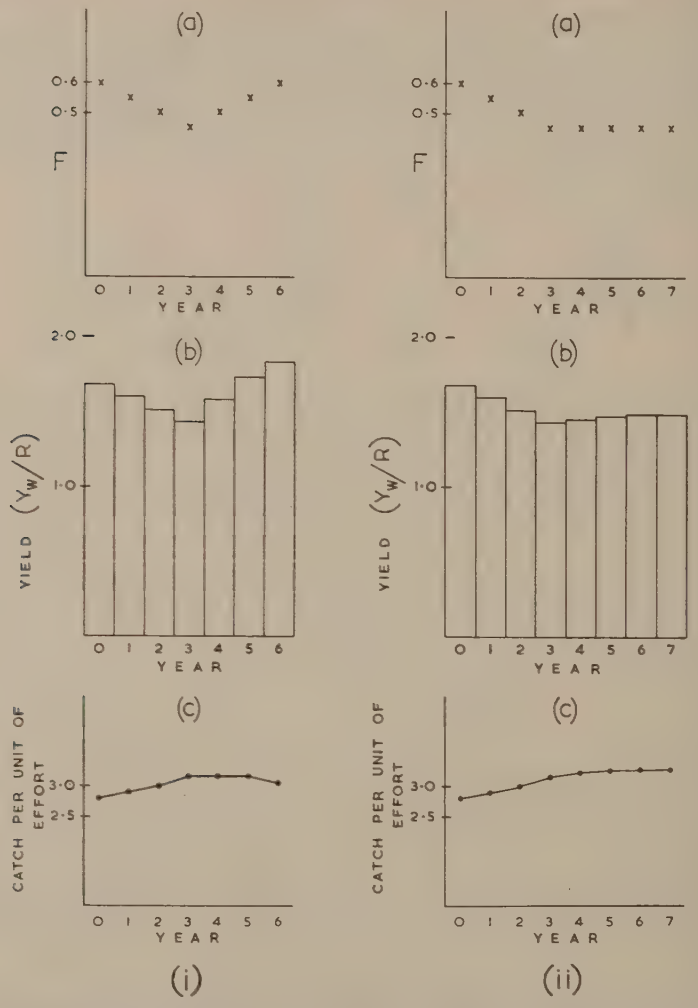

Figure 9. Yields of herring under oscillatory systems. Full explanation in text.

the yield increased above its previous level, because during the three years of relaxed fishing effort, the stock increased (Figure 9 (i) b). The changes in abundance are shown in Figure 9 (i) c: the catch per unit effort increases up till the third year after which it decreases, at first slowly and then in the sixth year, sharply. Thus, the oscillation in effort is very quickly reflected in an oscillation in stock.

The second type of oscillation is merely a reduction in fishing mortality from 0·6 to 0·45 in three years, after which it remains constant for four years

(Figure 9 (ii) a). The yield decreases as fishing mortality decreases and subsequently it rises slightly (Figure 9 (ii) b). The effect on the stock is shown in the change in catch per unit effort (Figure 9 (ii) c), changing in the opposite direction to that in fishing mortality, or effort.

We may compare the average values from the two types of oscillation as follows, in arbitrary units: —

		Yield/recruit	Catch/effort	Average fishing mortality
Fig. 9 (i)	Steady state	1·64	3·15	0·525
	Oscillatory state.....	1·625	3·05	0·525
Fig. 9 (ii)	Steady state	1·61	3·30	0·49
	Oscillatory state.....	1·57	3·24	0·49

The most important point is that for both types of oscillation, with the same average fishing mortality, the yield is less under the oscillatory state than it is under the steady state. More important, the catch/unit effort is greater under the steady state. This is because a greater proportion of the stock is lost by natural mortality in the oscillatory system. The result is that for a given catch/effort, a greater yield can be obtained under the steady state. In fact for a yield of 1·625, at a steady state catch per unit effort of 3·25, we would only need a fishing mortality of 0·50. Under the oscillatory system, more fishing effort would be needed (about 5%), working at a catch/unit effort of 3·05, which was 6% less.

Both systems illustrated show small changes in yield and in catch/effort of about 12% in catch and up to 20% in catch/effort. It is possible that such an oscillation did take place from 1930–37 (see Figure 1). In this case the variation in catch was nearly 30%. It is interesting that the same trend can be discerned in the average mortality rates (see Table 1). The recovery of effort could well be due to the 1929 year-class (see Table 6 in CUSHING and BURD, 1957).

The treatment so far has been that of a fishery with no variations in recruitment or in vulnerability. For the moment the effects of vulnerability must be ignored because they are not understood; the greatest source of variation in annual yield, however, is that due to recruitment, which may be of the order of five to six times.

An estimate of the variability of the annual yield due to recruitment changes has been made using the equation for yield in numbers (BEVERTON and HOLT, 1957).

$$\frac{Y_n}{R} = \frac{F_e^{-M^1}}{Z}(1 - e^{-(Z)\lambda})$$

where M^1 is the instantaneous coefficient of natural mortality in the pre-exploited phase.

A model yield from successive year-classes was calculated for twenty years, with recruitment varying randomly at the levels of 5, 10, 20, and 30; the annual yield was summed for each of the year-classes represented. The calculations were made at a number of values of F, with M constant at 0·25, and were made in two forms, firstly with partial recruitment at three years of age and secondly with full recruitment at three years of age. For the partial recruitment, it was assumed that the number of three year-old recruits was 55% of the total

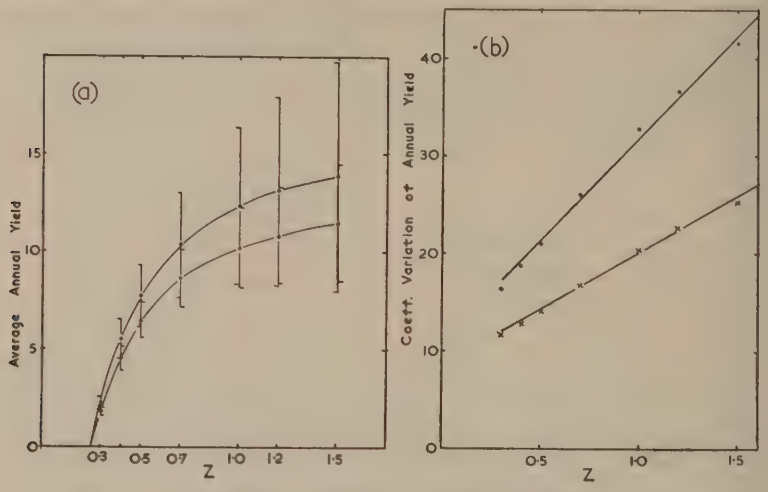

Figure 10. Variability of the yield of herring.

(a) Variability of the annual yield in numbers with increasing mortality. The upper curve is the yield when recruitment takes place at three years of age and the lower when it takes place partly at three and partly at four.

(b) Coefficient of variation of annual yield with increasing mortality. Upper and lower curves as in Figure 10 (a).

number of recruits reaching the fishery (CUSHING and BURD, 1957) at three and at four years of age. Thus the first method represents the form of recruitment before 1950–51 and the second represents that after that date.

Figure 10 (a) shows the yield in numbers as before and as after the change in recruitment. This corresponds to the differences in $\frac{Y_W}{R}$ shown in Figure 7 between the 1944–45 brood which lived before the 1950–51 recruitment change and the 1947–48 brood which lived after the recruitment change. The main difference due to the recruitment change is an increase in yield because fishing started somewhat earlier in the life of the fish.

Figure 10 (b) also shows the coefficient of variation of the annual yield calculated from the model. From the fourteen values of annual yield with varying recruitment, variances for each level of mortality were calculated; then a coefficient of variation $\frac{(100 \text{ var})}{\text{mean}}$ was calculated. From the model as shown in Figure 10 (b), it may be shown that under conditions of partial recruitment at three years old, with $(Z) = 0{\cdot}4 - 0{\cdot}5$, the coefficient of variation would be about 12%. Similarly under conditions of full recruitment at three years old, with $(Z) = 0{\cdot}75 - 0{\cdot}90$, the coefficient of variation would be 25%–30%. It is reasonable to assume that variability due to recruitment in recent years has more than doubled.

Returning to Figure 8, which shows the catch in weight/effort at different levels of fishing mortality for the 1947–48 brood, the error due to variability in recruitment is shown as dotted lines; this error is the coefficient of variation of

the yield in numbers applied to the catch per effort in weight. This is the coefficient of variation due to changes in recruitment and the differences due to calculating in numbers will only be small ones.

It is assumed that when $F = 0{\cdot}60$, the corresponding catch/effort is a limiting one and that when effort reaches this level an oscillatory system is set up. The "confidence limits" to the line of catch per effort (which are described by the coefficient of variation of the yield) show that if F was reduced to 0·40–0·45, there would only be one chance in 20 of the catch/effort reaching the limiting value at which fishing stops due to changes in recruitment. This is very important in the herring fishery because there are many small boats owned by single families, which under this treatment are equivalent to the large companies. Each stops fishing at the limiting value of catch/effort.

We may now consider the effect of the industrial fishery for immature fish on the yield of adult fish. The reduction in the adult yield due to the industrial fishery would be given by

$$1 - \frac{e^{-(t_{\varrho}' - t_{\varrho})(F^1 + M^1)}}{e^{-(t_{\varrho}' - t_{\varrho})M^1}},$$

where F^1 is the fishing mortality in the industrial fishery. It is to be hoped that this will be found adequately from the ICES tagging experiment and then it can be fitted directly in the yield curves described here.

VI. Discussion

This paper is concerned with the present state of the herring stocks in the Southern North Sea. That they have been reduced has not been questioned. The cause of reduction has been attributed to three factors: —

(1) the industrial fishery on the nursery ground (Hodgson, 1956);

(2) natural changes, in particular, emigration from the East Anglian area (Parrish and Craig, 1957);

(3) fishing (Cushing and Burd, 1957).

It has been shown in this paper that the reduction is probably not due to the industrial fishery in the manner of Hodgson's hypothesis, because for three successive years the best estimates of the numbers of four year-olds "lost" under his hypothesis are greater than the catches on the nursery ground.

On evidence available in 1956, mortality had risen recently more quickly than had the effort and so it was reasonable to postulate that the "surplus" mortality was really an effect of the emigration of older fish. However, the fact that catches had increased in step with mortality suggested that the drifters' shots had become more efficient.

Such an increase in efficiency was shown independently by dividing the fishing intensity (effort per unit area or statistical square in this case) by the number of shots. When the East Anglian effort was corrected by this efficiency factor, it was found that the total effort on the Downs stock obtained by raising the East Anglian effort by the ratio of the Southern Bight catch to the East Anglian catch, had increased since 1950 to much the same degree as mortality and catch. Hence the reduction in catches has probably been due to fishing.

If this description is accepted, the means of stabilizing the fishery are available.

The choice lies between a stable annual yield and an oscillatory annual yield. The deciding factor lies in the catch per unit of effort. If oscillation takes place, too much time is spent at or near the lower limit of the limiting value of catch per unit of effort. At the stable level, there will of course be variations in the catch/effort, but they will not reach the dangerous limiting level. The herring fishery includes a large proportion of small owners in all countries, who would survive on a stable system, but would leave the herring fishery when the system oscillates.

VII. Summary

1. From an analysis of variance of East Anglian mortality rates, it was shown that each estimate of mortality, by age or by year, was equally precise. Consequently, average mortality rates were used in subsequent work.

2. From maturity studies, it was shown that one quarter of the trawl catches on the Dogger area were composed of Downs fish.

3. A comparison of mortality changes with effort changes since 1928, showed that, since 1950, mortality had increased more rapidly than had the effort. As catch had increased as rapidly as mortality, it seemed likely that the efficiency of fishing had increased.

4. An estimate of increased efficiency was obtained independently by dividing the fishing intensity in each season by the number of shots made.

5. When the efficient effort at East Anglia was raised by the ratio of Downs catch to East Anglian catch, it was shown that effort had increased as rapidly as catch and mortality since 1950. A regression of mortality on effort was constructed: there was one chance in ten that its slope was different from zero. Using this regression, the best estimate of natural mortality from 1928–55 was 0·17.

6. An estimate of the loss to the Southern Bight fisheries due to the Bløden Ground industrial fishery was made by comparing the catch of a year-class on the Bløden Ground with the numbers in the stock in the Southern Bight of the same year-class. Taking into account hypothetical variations in natural mortality rate on the Bløden Ground and the proportions of Bløden Ground fish reaching the Southern Bight, an estimate of the loss to the Southern Bight fisheries was made — 20% in 1954.

Hodgson's hypothesis was tested by comparing his estimated loss of four year-old fish to the Southern Bight fisheries with the catch. It was shown that the estimated loss was 2–5 times as great as the catch in 1951 and 1952; hence it is likely that Hodgson's hypothesis was faulty.

7. Using the estimates of natural mortality and fishing mortality given above, the yield/recruit of herring was calculated. It was shown that a steady state yield was more efficient than that from an oscillatory system.

In the herring fisheries, there is a low limiting level of catch per unit effort, at which fishing stops. Variations in stock and yield are mainly due to variation in recruitment. From the observed variations in recruitment, the variability of yield and catch/unit effort is calculable. Thus if the limiting catch/effort corresponds to a fishing mortality of 0·6, that corresponding to a fishing mortality of 0·45 will never vary sufficiently due to recruitment to reach the dangerous limiting value.

References

Ancellin, J., 1953. "Hareng du sud de la Mer du Nord et de la Manche orientale, campagne de 1952–53". Ann. Biol. Copenhague, **9**: 202–05.

Andersson, K. A., 1954. "Studies on the fluctuations in the rate of growth of the herring in the Kattegat and the Skagerak". Rep. Inst. mar. Res. Lysekil, Ser. Biol., **3**.

Bertelsen, E., & Popp Madsen, K., 1953. "Young herring from the Bløden Ground area". Ann. Biol. Copenhague, **9**: 179–80.

Bertelsen, E., & Popp Madsen, K., 1954. "Young herring from the Bløden Ground area". Ann. Biol. Copenhague, **10**: 155–56.

Bertelsen, E., & Popp Madsen, K., 1956. "Young herring from the Bløden Ground area". Ann. Biol. Copenhague, **11**: 125–27.

Beverton, R. J. H., & Holt, S. J., 1957. "On the dynamics of exploited fish populations". Fish. Invest. Lond., Ser. 2, **19**.

Buchanan-Wollaston, H. J., 1933. "Some modern statistical methods: their application to the solution of herring race problems".J. Cons. int. Explor. Mer, **8**: 7–47.

Cushing, D. H., 1955. "On the autumn-spawned herring races of the North Sea". J. Cons. int. Explor. Mer, **21**: 44–60.

Cushing, D. H., & Burd, A. C., 1957. "On the herring of the southern North Sea". Fish. Invest. Lond., Ser. 2, **20** (11).

Einarsson, H., 1951. "Racial analyses of Icelandic herrings by means of the otoliths". Rapp. Cons. int. Explor. Mer, **128** (1): 55–74.

Gulland, J. A., 1955. "Estimation of growth and mortality in commercial fish populations". Fish. Invest. Lond., Ser. 2, **18** (9).

Hodgson, W. C., 1933. "Further experiments on the selective action of commercial drift nets". J. Cons. int. Explor. Mer, **8**: 344–54.

Hodgson, W. C., 1939. "An improved method of sampling herring shoals". Rapp. Cons. int. Explor. Mer, **110**: 31–38.

Hodgson, W. C., 1956. "Failure of the East Anglian fishery. Natural causes or what?" World Fish., **5** (1): 29–31.

Hodgson, W. C., 1956. "East Anglian failure (2). Is it death by natural causes?" World Fish., **5** (2): 52–54.

Hodgson, W. C., 1957. "The Herring and its fishery". Routledge and Kegan Paul.

Johansen, A. C., 1924. "On the summer- and autumn-spawning herrings of the North Sea". Medd. Komm. Havundersøg., Kbh., Ser. Fisk., **7** (5).

Parrish, B. B., & Craig, R. E., 1957. "Recent changes in the North Sea herring fisheries". Rapp. Cons. int. Explor. Mer, **143**, Pt. 1: 12–21.

Richardson, I. D., 1956. "Selection in drift nets". Paper presented to Comparative Fishing Committee of ICES, 1956.

Schnakenbeck, W., 1927. "Rassenuntersuchungen am Hering". Ber. Komm. Meeresforsch., N.F., **3**: 95–204.

Silliman, R. P., 1943. "Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). 5. A method of computing mortalities and replacements". US. Dept. Int., Fish. & Wildl. Serv., Spec. Sci. Rep.-Fish., 24.

Tungate, D. S., 1958. "Echo sounder surveys in the autumn of 1956". Fish. Invest. Lond., Ser. 2, **22** (2).

Widrig, T. M., 1954. "Method of estimating fish populations, with application to the Pacific sardine". US Dept. Int., Fish. & Wildl. Serv., Fish. Bull., **56**: 139–66.

Wood, H., Parrish, B. B., & Mcpherson, G., 1955. "Review of Scottish herring tagging experiments, 1948–53". Rapp. Cons. int. Explor. Mer, **140**, Pt. 2: 35–54.

Zijlstra, J. J., 1956. "On the spawning communities of the herring in the southern North Sea and the English Channel (preliminary results)". Rapp. Cons. int. Explor. Mer, **143** (2): 134–45.

Utilization of Algae for Growth by the Angelfish, *Holacanthus bermudensis**

By

David W. Menzel

Bermuda Biological Station for Research, St. George's, Bermuda

Introduction

The feeding habits of fishes as deduced from analyses of stomach contents have, on at least one occasion, led investigators to classify certain species which are browsers as entirely herbivorous (DAWSON, ALEEM, and HALSTEAD, 1955). This in itself does not seem contrary to existing knowledge of the feeding preferences of some fishes. However, from the nutritional point of view it is a little more difficult to conceive how fish are able to utilize the relatively poor food source of littoral marine algae for growth and maintenance.

Enumerations of the gastrointestinal contents of organisms have two major weaknesses; first, they are generally not carried on over a sufficient length of time to warrant anything but gross generalizations, since a fish's diet may change with season (as shown later); and second, they say little of organisms which may be ingested incidently, digested rapidly, but which may be most important to the nutritional requirements of the fish.

An examination of stomach contents revealed that a number of Bermuda reef fishes, the angelfish (*Holacanthus bermudensis*), and some members of the Chaetodontidae, Acanthuridae, and Scaridae ingest quantities of attached algae. This study was initiated to determine experimentally whether angelfish are able to grow on plant matter alone and if they are not, to attempt to identify the nutritional inadequacies in an algal diet.

Methods

The angelfish, one of the more common Bermuda reef fishes, is known to occur from a depth of 0·5 to at least 60 m. It reaches a maximum length and weight of about 30 cm and 800 g, and attains sexual maturity at 20 cm and 200 g.

* Contribution No. 247 from the Bermuda Biological Station. This study was supported by funds from the National Science Foundation and the Bermuda Government Fisheries Research Program.

An analysis of the contents of 35 stomachs collected during March and December (19°C) indicated that only plant matter was consumed. One animal fragment (crustacean leg) was found in a single stomach. The species of algae fed upon at these times consisted almost exclusively of *Caulerpa verticillata*, although *Enteromorpha* sp. and *Dictyota* sp. occasionally occurred in the stomachs. An additional 19 stomachs that were examined during July (28°C) included considerable animal matter. During October (23°C) the fish were still omnivorous. An index, by volume, of plant to animal matter in the stomachs for the period from July to October showed roughly one part animal to two parts plant matter. The animal matter consisted largely of small *Porifera* and soft parts of various coelenterates. Algae fed upon consisted largely of *Caulerpa crassifolia*, with some tips of *C. verticillata*, and small fragments of other species which were unidentifiable.

During March, *Enteromorpha salina* was used for feeding experiments since it was the only alga readily available in pure form and sufficient abundance. In July, 6 fish of various sizes were introduced into feeding tanks containing the following algae: *Avrainvillea* sp., *Caulerpa verticillata*, *C. crassifolia*, *Dictyota dichotoma*, *Bryopsis* sp., *Monostroma oxysperma*, and *Codium* sp. At the end of two days the fish were killed. The only species common to all stomachs was *Monostroma* and therefore it was chosen for feeding purposes.

Feeding experiments were carried on between 15. March and 4. April (19°C) for a 20-day period and during the first two weeks of July (28°C) for a 10-day period. Three experimental groups were composed of 4 to 7 fish that were fed together; Group 1 fish ranged in weight from 49 to 82 g; Group 2 fish from 100 to 178 g; and Group 3 fish from 210 to 302 g. Group 3 fish were sexually mature individuals, while the fish of Group 1 and 2 were immature.

Prior to weighing the fish were starved for a period of two days in order that they might empty their intestines. Excess water was removed by light blotting with paper towelling and the fish weighed to the nearest 0·1 g. An abundance of algae (*Monostroma oxysperma* or *Entermorpha salina*) was kept in the tanks at all times and unused plant material was removed daily before a new supply was offered.

The algae were washed carefully to remove associated animal matter and then weighed to the nearest 0·1 g. Since it was difficult to obtain the true wet weight of these plants, a large sample was first blotted on paper towelling and its approximate weight determined. An aliquot of this material was dried at 80°C. After unused algae were removed from the feeding tanks they were also dried and the amount eaten was calculated in terms of dry weight. An average of all moisture determinations was used to recalculate the wet weight of the food consumed.

Faeces were removed from the tanks daily with a siphon tube. The included water was passed through No. 2 plankton netting, collected, and refiltered through a Buchner funnel with No. 1 Whatman filter paper.

A series of control fish and the experimental fish were analysed for water, fat, protein, and energy content. Changes in the body composition of experimental fish were determined by the "sacrifice method" outlined by MAYNARD and LOOSLI (1956).

Entire animals were homogenized and dried at 80°C for the determination of their chemical composition. The following methods were used in the chemical analyses of food, fish, and faeces: —

Nitrogen and protein. Total and non-protein nitrogen were determined by the macro-Kjeldahl method (WILLARD and FURNHAM, 1940). Non-protein nitrogen was extracted with trichloracetic acid and the value obtained subtracted from the total nitrogen to give the amount of protein present.

Fat. According to the Association of Official Agriculture Chemists (1950).

Caloric content. One gramme samples were combusted in an oxygen bomb calorimeter (Parr Instrument Co., 1948).

For the measurement of their oxygen consumption, fish were allowed to come to rest for a period of 4 to 6 hours in continuous flow apparatus (KEYS, 1930). Water at the inlet and outlet was sampled every 4 hours for the period of a day and the resulting 6 determinations (Winkler method) were averaged to give the mean daily oxygen consumption.

Results

Results of the chemical analysis of *Enteromorpha* and *Monostroma* are presented in Table 1. *Caulerpa verticillata*, *C. crassifolia*, and *Dictyota dichotoma* were also analysed for nitrogen and energy content in order to permit comparison between the nutritional value of those algae fed in the laboratory and the algae commonly fed upon in nature. It is shown that they are nutritionally equivalent to *Monostroma*.

Considerable loss in weight (−2·7% to −4·2% of body weight) occurred among individual fish at 19°C, whereas at 28°C fish in Groups 1 and 2 gained 1·8% and 1·0% in weight respectively. The amount of food ingested each day, per unit body weight, varied little between size groups at 19°C. At the warmer temperature Groups 2 and 3 doubled their intake, whereas Group 1 fish increased it 3·5 times (Table 2).

During the various feeding periods, there was little difference in the percentage of ingested food that was absorbed through the intestine. This was determined by obtaining the difference in chemical constituents between the food ingested and faeces. The degree of absorption did not vary with temperature or the size of the fish, however different components of the food were absorbed at differential rates. Nitrogen seemed to be the most easily utilized of the various components with absorption values ranging between 82% and 91% (average 85·0). Between 63% and 79% (average 71·7) of the carbohydrates and 72% to 84% (average 77·7) of the energy was absorbed from the food. There is little reason to question the ability of angelfish to digest plant matter adequately since these values are roughly comparable to those obtained from ruminants (MAYNARD and LOOSLI, 1956).

The fact that some of the fish gained weight at 28°C at first leads one to believe that enough algae was ingested to enable these animals to grow. Measurements of changes in organic constituents of the body, however, show that no protein was deposited at any time (Table 3) and since protein deposition has been considered the criterion of "true growth" (GERKING, 1955) the question as to whether growth occurred at all is open to argument. That this should have been the case is not surprising when the nitrogen content of the algal diet is considered (Table 1). The fact that some weight was gained in these instances is attributed to increase in body lipids. It is shown (Table 3) that the fat content of Groups 1 and 2 fish increased 3·7 and 1·5 g respectively at 28°C. Loss in

Table 1

Composition of the food offered to angelfish, and the composition of some other algae commonly ingested in nature, in percentage of dry weight unless otherwise specified

(The ranges are given with the means in parentheses).

	Enteromorpha salina	*Monostroma oxysperma*	*Caulerpa verticillata*	*C. crassifolia*	*Dictyota dichotoma*
Water	81·4–86·1	78·2–83·0	80·2	82·2	85·0
(percentage of wet weight)	(84·3)	(80·7)			
Total nitrogen	1·45–2·36	0·95–1·15	1·64	1·55	2·34
	(1·73)	(1·01)			
Non-protein nitrogen	0·37–0·84	0·03			
Protein	6·9	6·3			
Fat	<1·0	3·5–5·1			
		(4·1)			
Ash	43·7	18·9			
Carbohydrate	49·4	70·7			
K.cal./g dry weight	1·59–1·72	2·56–2·57	2·91	2·62	2·48
	(1·67)	(2·56)			

Table 2

Changes in body weight of experimentally fed angelfish and the average amount of food eaten per day (percentages of initial body weight)

	°C	Number of fish	Weight change Maximum	Minimum	Average	Food intake
Group 1	19	6	−4·0	−1·8	−2·7	2·3
	28	8	+3·8	+0·7	+1·8	8·1
Group 2	19	6	−5·0	0·0	−3·2	2·6
	28	8	+3·6	0·0	+1·0	5·6
Group 3	19	6	−5·7	−3·8	−4·2	1·5
	28	8	−0·9	−0·2	−0·8	3·1

Table 3

Changes in fat, protein, and energy content in experimentally fed angelfish

	°C	Fat (g)	Protein (g)	Kilo-calories
Group 1	19	−1·5	−1·5	−21·9
	28	+3·7	−0·1	+34·4
Group 2	19	−8·0	−2·0	−85·0
	28	+1·5	−0·7	+10·2
Group 3	19	−5·9	−0·2	−56·0
	28	–	–	–

body weight at 19°C was, of course, accompanied by a decrease in both body fat and protein.

The energy balance of the fish was calculated in two ways: (1) using average oxygen consumption measurements, the energy expenditure of the angelfish was estimated by multiplying the amount of oxygen consumed over the length of the feeding period by 5·0. This is based on the assumption that the R Q of

Table 4

Comparison of energy balance determined by oxygen consumption and tissue analysis in angelfish (in kilocalories)

	Group 1		Group 2		Group 3	
	19°C	28°C	19°C	28°C	19°C	28°C
Oxygen consumption	−20·8	+31·4	−69·5	+13·4	−47·5	−17·8
Tissue analysis	−21·9	+34·4	−85·0	+10·2	−56·0	–
Percentage change in body weight	−2·7	+1·8	−3·2	+1·0	−4·2	−0·8

angelfish on a plant diet is unity and that 5 kilocalories are liberated for every litre of oxygen consumed (HAWK, OSER, and SUMMERSON, 1954); (2) aliquots from experimental and control fish were combusted in a bomb calorimeter and energy loss or gain calculated from the beginning and final weight of the fish.

These two methods yielded remarkably similar results (Table 4) and show, as might be expected, that the ability of angelfish to maintain weight is correlated with its energy balance. It seems unquestionable then that the failure of these fish to deposit protein was associated with nitrogen deficiency in the diet and not due to the fact that insufficient energy was ingested for maintenance.

In order to offset the possibility that weight loss was the result of laboratory confinement and not dietary restriction, a group of 6 fish (size group 1) was later fed on a diet of mixed algae and crushed mussel at 28°C. When nitrogen intake was supplemented in this way, weight gains ranged from 4·0% to 6·2% (average 5·1) of their body in a 10-day period. Rates of food intake (by weight) were roughly maintained at the same level as when algae alone were fed, but since it was virtually impossible to recover unused mussel remains, further energetic relationships were not determined.

Discussion

Angelfish feed largely on attached algae during winter months, although they are definitely omnivorous at other times of the year. However, from the nutritional point of view, volumetric determination of organisms in the stomachs of omnivorous fishes has little significance. One gramme of plant matter (*Monostroma*) has approximately only 50% of the caloric value and 14% of the protein content of animal flesh. VINOGRADOV (1953) has summarized the work of a large number of authors, and these data suggest that most attached marine algae have a nitrogen content similar to that of *Monostroma*. Notable exceptions are some of the Rhodophyta (namely *Porphyra*).

On the other hand, analyses of various unicellular chlorophytes have shown that protein may constitute from 41% to 53%, carbohydrates from 26% to 38%, and lipids from 20% to 27%, of their dry weight (KETCHUM and REDFIELD, 1949). If these organisms are easily digested by fishes certain of the smaller algae could be excellent food sources. It is unlikely, however, that fishes can selectively filter unicellular plants from water and not include appreciable animal matter. Whether animal matter is ingested intentionally or accidentally by plant feeding fish is unimportant. It appears that some animal matter is necessary in the diet to insure growth.

Acknowledgements

The author is indebted to Dr. John E. Bardach for assistance in the formulation and execution of this study, to Dr. Wm. Randolph Taylor for the identification of algae, and to the Director and Staff of Bermuda Biological Station.

Summary

1. A series of experiments are desribed in which the predominantly herbivorous angelfish (*Holacanthus bermudensis*) was fed on algae alone at two temperatures (19° and 28°C).

2. It was shown that some weight was gained at 28°C but that weight loss occurred at 19°. Weight gain at 28°C was attributed to the deposition of lipids. No protein was deposited at any time.

3. These results lead one to conclude that it is doubtful whether angelfish can grow on plant matter alone unless their rate of intake in nature far exceeds the observed maximum feeding rates in captivity.

References

Association of Official Agriculture Chemists, 1950. "Methods of Analysis". 7th ed., Washington, D.C.: The Association, 910 pp.

Dawson, E. Yale, Aleem, A. A., & Halstead, B. W., 1955. "Marine algae from Palmyra Island with special reference to the feeding habits and toxicology of reef fishes". Allan Hancock Found. Publ., Occ. Pap., 17: 39 pp.

Gerking, Shelby D., 1955. "Influence of rate of feeding on body composition and protein metabolism of bluegill sunfish". Physiol. Zool., **28**: 67–282.

Hawk, Ph. B., Oser, B. L., & Summerson, W. H., 1954. "Practical Physiological Chemistry". 13th ed., New York: The Blakiston Co., Inc., 1323 pp.

Ketchum, B. H., & Redfield, A. C., 1949. "Some physical and chemical characteristics of algae grown in mass culture". J. cell. comp. Physiol., **33**: 281–99.

Keys, A. B., 1930. "The measurement of respiratory exchange of aquatic animals". Biol. Bull. Woods Hole, **59**: 187–98.

Maynard, L. A., & Loosli, J. K., 1956. "Animal Nutrition". 4th ed., New York: McGraw-Hill Book Co., Inc., 484 pp.

Parr Instrument Company, 1948. "Oxygen bomb calorimetry and oxygen bomb combustion methods". Moline: Parr Instrument Co., Manual No. 120: 80 pp.

Vinogradov, A. P., 1953. "The Elementary Chemical Composition of Marine Organisms". New Haven: Sears Found. Mar. Res., Yale Univ., 647 pp.

Willard, H. H., and Furnam, N. H., 1940. "Elementary Quantitative Analysis". 3rd ed., New York: D. Van Nostrand Co., Inc., 531 pp.

The Determination of the Age and Growth of Pike *(Esox lucius* L.*)* from Scales and Opercular Bones

By

Winifred E. Frost and **Charlotte Kipling**

Freshwater Biological Association, The Ferry House, Ambleside, England

Introduction

In fishery biology the annual "rings", "checks", or "annuli" on certain structures of the fish, such as the scales, opercular bones, otoliths, vertebrae, fin rays etc., are used to determine the age and sometimes, the growth of a fish. For the pike, *Esox lucius* L., scales have been used for this purpose by both European and American workers, but in a study of this species in Windermere opercular bones have been used as well as scales. This is apparently the first time that these bones have been used to determine the age and growth of the pike. Both the scales and opercular bones of the pike of Windermere presented difficulties and early results obtained from "readings" of them were unsatisfactory and inconsistent. Therefore the use of scales and bones has been critically examined in the hope that a satisfactory method of determining the age and growth of the pike from one or both of these structures might be evolved and this paper deals with the methods and results of the examination and the conclusions derived therefrom. Throughout this paper, which is essentially concerned with technique, only growth in length is considered and no reference is made to weight.

Materials

Material from Windermere, which includes scales and opercular bones, has been collected from 1944 to 1957. Most of the pike (about 5,000) have been taken in gill nets (mesh size $2\frac{1}{2}''$ [6·3 cm] bar) set in the lake each year from October to March, and from these fish scales and operculars have been taken. In addition, samples of scales have been collected from about 2,000 pike caught in perch traps (mid-April to mid-June) and about 250 opercular bones have been taken from these fish. Pike from standard monthly seines have also provided some 300 scales and about 150 operculars. About 250 specimens of

small pike, 0+ fish, were taken by seine and angling and hand net. As no serious attempt was made to rear pike in aquaria or ponds there is (with the exception of one fish) no material of known age available. Since 1949 over 1500 pike, mostly taken in perch traps, have been tagged with individually numbered tags on the upper jaw (maxilla) or on the opercular bone (the majority on the former), and released in the lake. By December 1957, more than a third of these tagged fish had been recaptured in perch traps, gill nets, seines, and by anglers. Scales were taken at the time of tagging and at recapture, and in addition the operculars were taken off those recaptured fish which were killed.

Methods

Measurements

All fish were measured from the snout to fork of the caudal fin (for a few specimens, covering a representative size range from 5 to 103 cm, length to the distal end of the longest caudal fin ray was also taken, i.e., the total length. The mean ratio of total length to fork length for these 157 fish was 1:1·06. The ratios did not vary with the size of the fish). Fish caught in gill nets from 1944 to 1952 were measured to the centimetre below and the necessary correction of 0·5 cm added to the means, thereafter the fish were measured to the millimetre below. All tagged pike were measured to the nearest millimetre, as were specimens caught by seine, angling, and hand net. The sex and condition of the gonad of the fish was determined by internal examination. The age of the pike is recorded so that fish in their first year of life belong to age-group 0, those in their second year of life to age-group I, in their third year to age-group II and so on, whereas fish which have completed their first year of life are recorded as age 1 and so on.

Treatment of scales and operculars

From experience the following technique has been adopted. The left opercular bone is removed with a scalpel and if immediately put into hot water for a few minutes it can be cleaned easily with a cloth between thumb and finger. When it is dry the rings on the bone are visible and these are much clearer after some months of storage of the bones. They are numbered and then stored in envelopes or jars, properly protected from predation by mice, insects, or fungi!

The scales are scraped off the pike from an area just above the lateral line and about midway along the body length. Here scales are first laid down (p. 323), moreover it was found that in this region there was a greater number of scales of typical form and large size than in samples from other parts of the body. Scales are stored in envelopes and when needed three or four with good centres are soaked in 4% NaOH solution overnight and then cleaned with a brush. They are mounted dry between two glass microscope slides.

Technique for reading opercular bones and scales

The rings on the opercular can be seen with the naked eye but a more reliable count of them can be made under a low power binocular microscope by reflected light on a dark background (Plate 2a). A scale projecting apparatus, with its greater magnification and transmitted light, gives the best and most

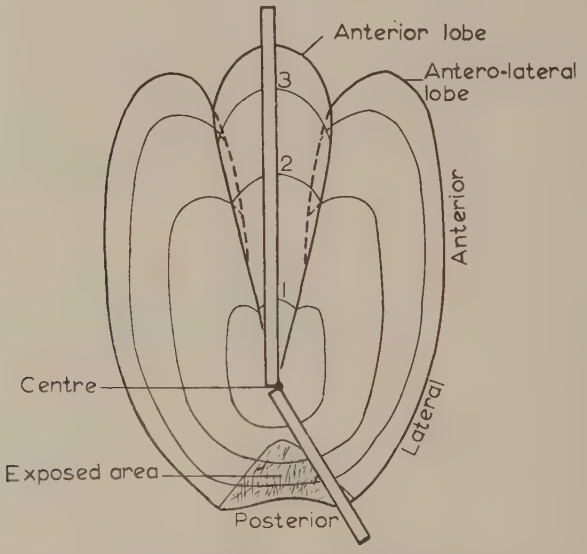

Figure 1. Diagram of pike scale showing position of cardboard strips used for back-calculation.

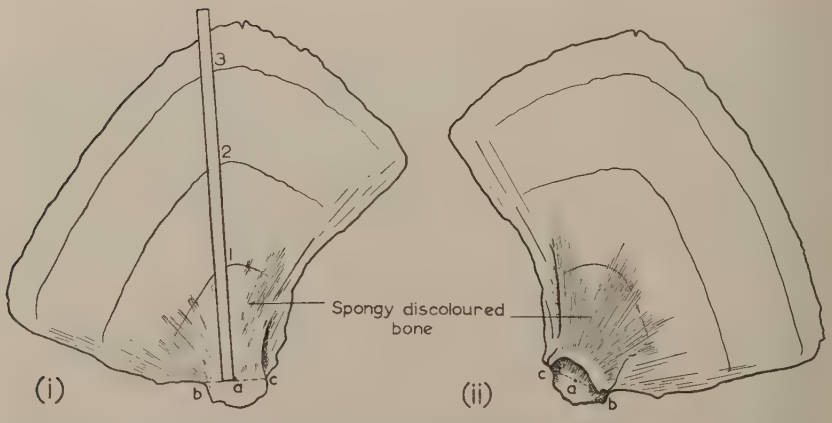

Figure 2. Diagram of pike opercular bone.
(i) Convex (outer) side, showing position of cardboard strip used for back-calculation on projected bone.
(ii) Concave (inner) side showing articulating surface of bone.
a = chosen centre of growth of bone.
b and c = indentations seen on outline of projected bone.

reliable results and is essential for accurate measurement of the rings (back-calculation (Plate 2b). The apparatus used magnifies the bone 5·3 times natural size. It was usual when projecting the bone to rest it on a glass plate but it was found that if the bone were in a glass dish of xylol instead of on the plate a much clearer image was obtained, and that this particularly applied to the thicker bones. This technique is now used for all the bones. The bone is slightly curved but it was found that measurements of the rings were much the same whether the concave or convex side of the bone received the light. In practice the convex (outer) side is placed on the stage of the projector so that the concave faces the source of artificial light.

The same projector is used for reading the scale but set up to give a higher magnification, namely 20 times natural size.

The image of both scales and bones is cast downwards on to a sheet of white paper on the table beneath the projector. To back-calculate growth a narrow strip of cardboard is laid on the image and on this the position of the rings is marked off with a pencil. The edge of the cardboard strip is placed at the centre of the scale and set on the long axis on the anterior part of the scale and at an angle on the posterior part as shown in Figure 1, on the opercular the strip is set at right angles to the line used in locating the chosen centre of the bone (p. 330). This centre is taken to be the point where a line drawn from the opposite indentations of the articulating "nub" is bisected. (Fig. 2(i)).

Ford-Walford plots

The graphic method described by WALFORD (1946) and summarized by ROUNSEFELL and EVERHART (1953) for determining age and growth has been found most useful in studying the age and growth of pike, and has proved essential to the use of operculars for this purpose. The formula on which this graphic method is based is essentially the same as that given by FORD (1933) and assumes that the successive yearly increments added to length decrease in magnitude in geometric progression, until a limiting value of total length (ultimate length) is approached. This pattern of growth is similar to that described by the equation of organic growth which has been derived by VON BERTALANFFY (1957).

WALFORD changes the form of the growth curve by plotting "length at age n" against "length at age $n + 1$", which gives a straight line relationship when the above assumptions are fulfilled, much simplifying the application of the method. A theoretical example is shown in Figure 3(a). The first year length is given by the intercept on the y axis (length at $0 + 1$), and the ultimate length at the intercept with the diagonal. The ultimate length is that length to which the growth pattern is directed, individual fish which come near to this length will continue to grow but probably at a different rate.

To plot the data thus, the age of the fish need not be known, a fact obviously of great importance when there is the possibility of missing annuli. Information on the length in two successive years (derived from tagged fish, or back-calculations) gives one point on the line, in three successive years two points etc., or knowledge of past catches from the same environment can supply information on the probable ultimate length, or, with more chance of error, first year length. Once any two points are fixed the line can be drawn, and the growth throughout life found by successive estimates. Length at age 1, see Figure 3(a),

p. 319, is found on the x axis and the corresponding value on the line read off from the y axis for length at age 2, and so on, or the estimates can be made in the opposite direction starting from any point on the line plotted at the end of any year's growth and working back to length at age 1. In this case a check can be made, as length at age 1 on the x axis must agree with the intercept on the y axis.

Growth thus determined cannot, of course, take into account variations caused by a good or bad growth season or individual irregularities. It is implied in the assumptions that the type of growth throughout life is fixed in the first year: once a fast grower always a fast grower and vice versa. In general the growth of pike in Windermere has been found to follow a linear relationship when plotted in the above manner, both for individual fish and means of various samples (Fig. 3), which makes it possible to use this technique for age and growth determinations.

Results

Determination of age and growth from the scales

Determination of age. On the scales of a fish are fine rings or circuli, the pattern of these rings is not uniform but shows interruptions or checks. When these are established as of annual occurrence then their number corresponds to the number of years of the fish's life. The check often consists of a number of narrowly spaced circuli, but the detailed appearance of it differs with the species of fish.

The shape of the pike scale is shown in Figure 1. The anterior part of the scale, which is the buried portion, is usually tricuspid, the posterior and protruding part, which comprises less than a third of the scale area, is rounded. Both parts of the scale have fine rings or circuli. These are not uniformly spaced but are arranged in alternate groups of widely and narrowly spaced circuli, a grouping which is much better defined on the anterior than the posterior part of the scale. Usually, but not always, one or two fragmented or irregular circuli occur among or at the anterior edge of the group of narrowly spaced circuli. On the anterior lobes of the scale this fragmentation produces a disrupted or "beaded" look, and at the sides a thin interrupted white line effect which cuts over into the circuli, the whole giving the check or annulus on the anterior part of the scale. On the posterior part of the scale fragmentation is more or less replaced by an absence of circuli and the hyaline layer so exposed gives a white line, which gives the check or annulus on the posterior part of the scale (Plate 1a and b),

The curious pattern, a chain-like deposition of the circuli, which Williams (1955) found anteriorly immediately after the first annulus on some pike scales from Michigan, U.S.A., was not found on the scales of Windermere pike.

To justify age determination of the pike from these checks on the scales it must be established that they are of annual occurrence. There are several methods of doing this, including that used by Williams (1955) who demonstrated the yearly occurrence of the annuli by examination of scales of pike of known age sampled over three years. Three attempts to rear pike for this purpose were made with Windermere specimens but only one fish survived more than one growing season. This specimen, which measured 5·5 cm when 0+ in June 1949, registered one annulus on the scale (Plate 1c) when it died

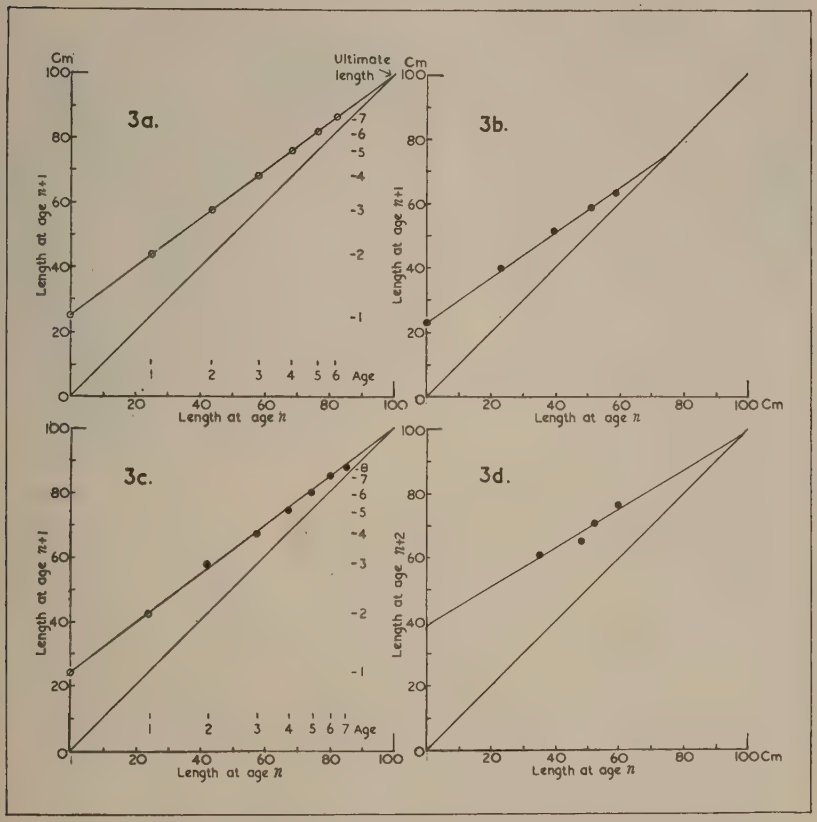

Figure 3. Walford plots of pike growth. On each plot the lower line is the diagonal. Open circles denote theoretical growth derived from the plots.

(a) Theoretical growth. This plot is based on two assumptions, that length at age 1 = 25 cm and that ultimate length = 100 cm. (These figures correspond to the growth of fast growing female pike in Windermere, see Table 3.) From the line joining 25 cm on the y axis to 100 cm on the diagonal theoretical growth for the first seven years has been derived, as described on page 317.

(b) Mean back-calculated growth. This plot shows the mean lengths at ages 1 to 5 of 54 male pike caught in gill nets 1946–1947 when aged 5 and over. The lengths were back-calculated from the opercular bones, using estimates for missing early annuli when necessary. To derive theoretical growth the line joining 23 cm on the y axis to 75 cm on the diagonal has been used. It agrees closely with the back-calculated growth. See Table 7.

(c) Individual back-calculated growth and example of missing first annulus. The black circles on this plot show the growth back-calculated from the opercular bone of a female pike (log number P 118(7)). The length of this fish back-calculated to the innermost visible annulus was 42·4 cm. To estimate its length at age 1 a line has been drawn by eye from 100 cm on the diagonal to fit the black circles as closely as possible. This line cuts the y axis at 24 cm, which therefore gives the estimate of length of this fish at age 1. Taking 24 cm as "Length at age n (= 1)", "Length at age $n + 1$ (= 2)" is seen from the line to be

42·5 cm. The innermost visible annulus, which was read to 42·4 cm, is therefore the second annulus, and the fish is aged 8.

(d) Estimation of length at age 2. These four points are plotted from the observed measurements of 4 female pike which were absent exactly two years between tagging and recapture. The line of best fit has been calculated by the method of least squares. It cuts the *y* axis at 38·9 cm, which therefore gives the estimate of length at age 2, two years having elapsed between each pair of measurements. It cuts the diagonal at 98·3 cm, thus further confirming the choice of 100 cm as the ultimate length for females.

November 1950 at 16·2 cm, and this annulus gave a back-calculated length (corrected) of 12·5 cm.

For the pike of Windermere the main proof of the annual occurrence of the checks is provided by the study of the scales of recaptured tagged fish. Scales were taken off each pike when it was tagged and also when it was recaptured, which might be any time from a few days to three years later. The number of annuli recorded on the scales of the returned fish agreed with the known years of absence since the fish was marked. This proof is best illustrated by photographs of scales taken at the time of tagging and on recapture as shown in Plate 1 d and e. The evidence from returned tagged fish that the check or annulus was of annual occurrence has been accepted as sufficient proof of this phenomenon so that further evidence from other methods used in fishery practice was deemed unnecessary.

That the annuli are annual in occurrence justifies a count of them to find the age of the pike. But certain difficulties in reading the age from scales have been encountered. On some scales it is difficult to identify the first true annulus, on both anterior and posterior parts of the scale, because there may be an abrupt change of growth during the first year which results in a check (Plate 1 b). Back-calculation of growth to this "first" annulus reveals that it is false, for such growth will be much below that expected for the first year. Williams (1955), who also found this false annulus, suggests that it is associated with a change from insect to a fish diet during the first year of life, which explanation could also apply to Windermere material (Frost, 1954).

In subsequent years false annuli or summer checks may occur on scales and they are difficult to detect because in pattern they may closely resemble the true annuli. If a scale shows two annuli unexpectedly close together it is reasonable to suspect that one of them is false, a suspicion which would be increased if, in addition, there was a discrepancy with the age and growth readings as obtained from the opercular bone of the fish (p. 330). (It may be noted here that false annuli are much easier to detect on the bone than on the scale; p. 328.) On the other hand, it is possible to make a mistake because there have been instances when a true check has been accepted as a false annulus. The false annulus does differ slightly in pattern from the true annulus, for although the fragmented look of the circuli which characterizes the true annulus is present, to some extent, on the anterior part and there is also a suggestion of the white line at the sides of the scale, posteriorly this latter often fades out. Williams (1955) has made a most detailed study of the "mid-summer false annulus", particularly of its form and methods of identifying it, based largely on scales from pike of known age. He finds that "the false check may consist of a hyaline line on the scale or of an abrupt crowding of the circuli either followed by the wider spacing of more rapid growth or a continuation of the closely-approximated circuli". The false check "may pass entirely round the scale as does an annulus

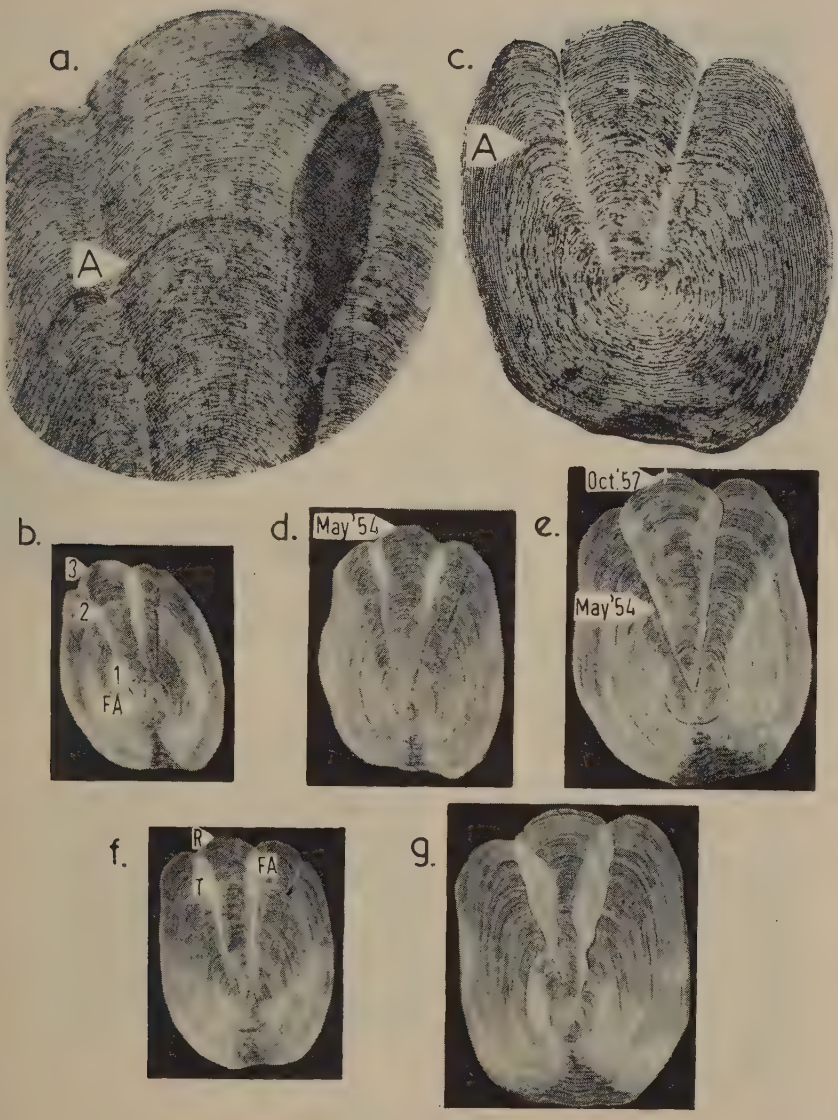

Plate 1. Pike scales.
See explanation, page 321.

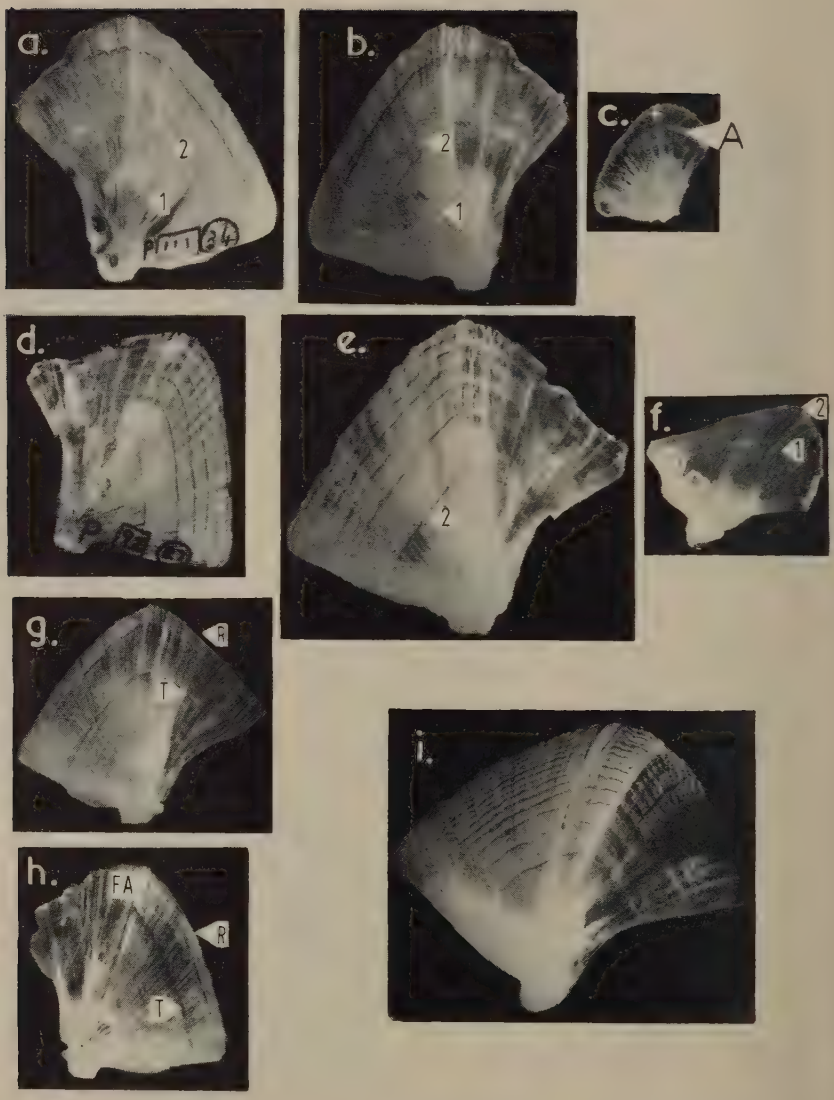

Plate 2. Operculars.

Explanation of Plate 1.

(a) Enlargement of part of scale (b) to show detail of the annulus, A, note narrowly spaced and fragmented circuli.
(b) Scale from 54·0 cm pike, well defined annuli anteriorly and posteriorly, age 3 years, last on edge: false annulus seen in first year.
(c) Scale from 16·2 cm pike reared 1½ years in aquarium showing one annulus, A, and plus growth: opercular of same fish, Plate 2 (c).
(d) Scale from 42·8 cm pike taken at time of tagging, May 1954, age 2 years.
(e) Scale from same fish (d), but lower magnification, at recapture 80·3 cm October 1957 3+ years later, showing 3 additional annuli and plus growth. (This fish a notably fast grower.)
(f) Scale from 61·0 cm returned tagged pike away one year, T tag, R return, showing an intermediate annulus which must therefore be false, FA. Opercular same fish, Plate 2 (h).
(g) Scale from 100 cm female, annuli not clear, possibly 12 anteriorly, compare opercular of same fish (Plate 2 (i)) which has 14 annuli, last on edge, clearly seen; the first missing.

Explanation of Plate 2.

(a) Opercular from 64·5 cm pike seen by reflected light, first annulus visible, female age 4 years, last on edge.
(b) Same opercular (a) when projected for reading by transmitted light, the standard practice.
(c) Opercular from 16·2 cm pike reared 1½ years in aquarium showing one annulus, A, and plus growth: scale of same fish, Plate 1 (c).
(d) Opercular from 64·5 cm pike seen by reflected light, first annulus missing, male age 8 years, i.e. 1 missing and 7 visible, last on edge.
(e) Same (d) but different magnification, seen by transmitted light.
(f) Opercular from 27·0 cm pike, age 2 years, showing first annulus visible, this usual in young fish.
(g) Opercular from 58·0 cm returned tagged pike (T, tag May 1955, R, return Aug. 1956). Fish away 1 year 3 months. Length back-calculated to annulus next but one to edge corresponds to known length at time of tagging, proving annulus is annual.
(h) Opercular from 61·0 cm returned tagged pike away one year showing an intermediate annulus which must therefore be false. Scale same fish, Plate 1 (f).
(i) Opercular from 100 cm female age 15 years, i.e., 14 visible and 1 missing annuli, showing that in big fish annuli much clearer on bone than on the scale, Plate 1 (g).

or it may be present only on a part, most often it is present from the antero-lateral region to the posterolateral region of the scale. It is usually not present on the extreme anterior lobe nor is it usually pronounced at the extreme high anterolateral region of the scale, i. e., the inner portion of the two outer lobes". From which he concludes that "a good criterion for recognising a false annulus in many cases is its absence at the anterior or high anterolateral fields since annuli usually are distinct here whereas the false annuli are not". As a more precise method of determining a check as false or true "counts [of the circuli] were made from the annulus to the most distant point at the anterolateral margin and (on the same side of the scale) from the annulus to the posterolateral margin as near to the beginning of the exposed posterior section as possible". Then if "the number of anterolateral circuli is more than twice the number of posterolateral circuli, the mark is likely to be a false check", conversely if less than twice the number then the mark is likely to be a true annulus. False annuli on the scales of pike of Windermere were suspected as such from their form (on the criteria mentioned earlier in this paragraph) and usually proved so by relating the growth increment involved with comparable increments as obtained from other sources. On the scales of returned tagged fish the presence of false annuli is certain when more annuli are seen than the known years of absence

Table 1

Examples of back-calculations of length (cm) from difficult scales and operculars of individual fish. Both fish have the first annulus missing on the opercular and other annuli have been missed on the scales. The opercular readings have been accepted from age 2 (37·0 and 45·0 cm) upwards

Male		Female	
Log No. P 182 (12)		Log No. P 182 (11)	
Scales	Opercular	Scales	Opercular
16·9	37·0	26·6	45·0
36·8	50·0	46·6	59·9
52·5	56·5	65·8	67·0
60·0	59·8	74·2	73·9
64·4	62·9	79·9	80·6
67·4	65·5	86·8	85·8
69·7	68·2	92·2	90·0
72·1	69·9	95·6	93·2
74·3	71·7	98·2	95·8
75·0	73·3	100·0	98·4
–	75·0	–	100·0

(Plate 1 f). Finally false annuli may be suspected (justifiably or not) when the age as determined from the scale differs appreciably from that obtained from the opercular bone, for although false annuli are also found on the bone they appear to occur less often and moreover are usually much easier to identify than those on the scale.

Comparison of the age as determined from the anterior part of the scale and from the opercular bone indicates that, in some older fish, annuli on the anterior part of the scale have been missed (Plate 1 g). Two examples from individual fish are shown in Table 1. In both these and in most other cases after comparison of increments of growth the opercular reading has been accepted in preference to the scale. The main reason for the differences seems to be that in the middle years of the fish's life "true" annuli on the scale have been considered to be "false" and have been omitted.

The annulus on the anterior part of the scale can pass round, but with a different pattern, to the posterior part (p. 318). This usually makes it possible to confirm the age, i.e., the number of anterior annuli, by a count of the posterior annuli, particularly as on some scales the white hyaline line which is the check on the posterior part is clearer than the narrow and fragmented annuli that give the check on the anterior part. The age of 85 fish ranging from 12 to 102 cm was read from both anterior and posterior annuli on the scale. On fish of up to about five years the number of annuli seen anteriorly and posteriorly was the same but with increasing age there was a discrepancy, sometimes amounting to three years, between the two readings, and in most but not all cases the anterior part gave the higher number. When this was so the discrepancy may be explained by the inclusion of false annuli in the anterior count since these false checks may have no counterpart on the posterior part of the scale (page 320). Alternatively if the posterior part has the higher number it may be due to omission of true annuli on the anterior part because they were mistaken for false ones. In older pike the annuli on the posterior part of the scale, particularly those near the edge, can be congested and ill defined. This makes it difficult to relate the anterior and posterior part of the same annulus,

with the result that the two parts can be counted as different annuli so that the ages as read from the anterior and posterior part of the scale differ. In addition, if the age of a large (and old fish) is read from the posterior part of the scale only there is a likelihood of an error because the congestion of the annuli here often makes it difficult to dissociate one annulus from another.

To find out when scales are laid down some specimens of 0-group fish, young-of-the-year, were examined. Those of 3·4 cm and less had no scales. The smallest specimen with scales was 3·6 cm, a fish caught in June, but as it already showed three circuli the platelet was probably laid down when the fish was a little smaller; another June-caught pike of 3·9 cm had similar scales. A specimen of 4·0 cm, caught in mid-July, had scales with 5 and 6 circuli. On this and similar evidence it may be accepted that the pike puts on scales when it is about 3·5 cm long and that in Windermere this length is usually attained sometime in June. It was noted that the scales first appeared just above and below the lateral line and practically simultaneously along the whole body length. A fish of 3·8 cm caught in late June had still no scales on the back or belly.

The exact time of year when the annulus is formed on the scale is not easy to determine as it is difficult to detect it at the edge of the scale until some plus growth has also been laid down, moreover the ill defined boundary of the annulus adds to this difficulty. The pattern at the edge of the scales taken from fish of different sizes and caught from February to July has been examined and recorded as "annulus not yet formed", "annulus forming", and "plus growth present". On Figure 4 these records are plotted for date against length of the fish. The figure shows that from mid-February to mid-May the annulus may be in process of forming. As almost all the fish examined in late April and early May have the annulus forming or already formed (the latter evident from the new (plus) growth outside the annulus) we may take it that the time of annulus formation on the scales of pike of Windermere is, in general, the first half of May. Hartley (1947) notes that "In East Anglia the late summer is the season of formation of checks on the scales", and Williams (1955) found that in the southern latitude of Michigan, U.S.A., the time of annulus formation ranges from early March to 1. June, and in the middle and northern latitudes of the State from late March to late June.

On the evidence from Windermere and because many recently hatched pike have been found in early and mid-May the conventional birthday of pike of Windermere is taken as 1. May.

Determination of growth. The "back-calculation" of growth of a fish from its scales has been applied to many species. The method is based on the annual character of the check and on there being a proportional relationship between the growth of the fish and its scales.

In age and growth studies of the pike back-calculation of growth (also often referred to as "estimated growth" but *not* used in this sense in this paper) has been used by several workers including Alm (1919, 1921), Nilsson (1921), Haakh (1929), van Engel (1940), Miller and Kennedy (1948), Healy (1955), Oliva (1956), and Munro (1957); of these Miller and Kennedy, Healy, and Oliva, justify in different ways the calculation of growth of the fish, although none of them presents proof of the validity of the method and in some published tables Lee's phenomenon is apparent but unexplained.

Early in the present investigation attempts were made to back-calculate the annual increments in length from checks on the scales.

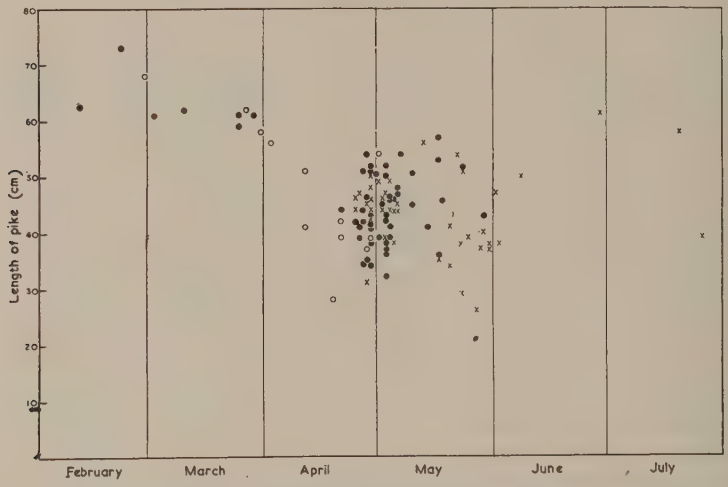

Figure 4. Time of annulus formation on scales.
Open circles = annulus not yet formed; black circles = annulus forming; crosses = plus growth present.

At first these calculations were made from the annuli on the anterior part of the scale (the usual fishery practice) later they were also made from the annuli on the posterior part (Fig. 1); no calculations were made laterally on the scale, although it was learned later that this was the technique of Miller and Kennedy (1948) and Oliva (1956), who were the only workers who did not read the anterior lobe of the scale.

Throughout the present investigation it was found that, for purposes of back-calculation, it was difficult to "pin-point" the limits of the annulus, and it was soon realized that this was definitely one of the reasons for the inconsistencies which marked the results obtained from back-calculation. Under low power magnification the annulus, both anterior and posterior, appears to be reasonably well defined, but when the scale is projected for back-calculation the outer edge or boundary of the annulus, particularly on the anterior part and more especially in older fish, is often difficult to locate precisely with the result that growth as calculated from the measurement made on the scale may differ, sometimes markedly, from the growth actually made.

It was thought unlikely, however, that such a technical fault provided the whole explanation of the discrepancies which characterized growth as calculated from scales, for it was found that: —

(1) Growth as back-calculated from the anterior part of the scale of a fish which had been tagged and recovered later showed poor agreement between the measured length of the fish when it was tagged and the length at that time as back-calculated on subsequent recapture; such calculations from the posterior part of the scale sometimes showed closer agreement.

(2) Lengths back-calculated from the anterior and from the posterior parts of the same scale and for the same year of life, did not always agree. For a few fish there was good agreement between the readings from the two sources,

notably for fish of up to three years old, but for the majority there were discrepancies (often a difference of 5 or 6 cm) between calculated lengths as made to the anterior and posterior annuli.

(3) Growth as back-calculated from the anterior part of the scale did not agree with that back-calculated from the opercular bone, although there was sometimes quite good agreement between back-calculations from the bone and the posterior part of the scale.

In view of these anomalies the possibility that the growth in length of the pike and the growth of its scales were not in direct proportion was therefore examined. To do this the length of the scales as recorded on the cardboard strips used for back-calculation were measured; these measurements, made for both the anterior and posterior parts of the scale, were plotted against the lengths of the individual fish from which they were taken. (Fig. 5(a)). The figure shows that the points for the anterior part of the scale lie on a curve, which indicates that growth of the anterior part of the scale and the growth of the body of the pike is allometric. On the other hand the points for the posterior part of the scale lie on a straight line, which indicates that the growth of the posterior part of the scale and of the body of the pike is isometric. This latter line cuts the x axis at 3·5 cm which gives the length at which scales were laid down (coinciding with the length found by observation, p. 323). Therefore direct proportion could be used for back-calculation from the annuli on the posterior part of the scale, provided that allowance is made for the length of the fish when the scale was laid down. However, although the posterior annuli appear to be reasonably well defined, it can be difficult, especially in older fish, to locate precisely the boundary of the annulus, consequently growth estimates obtained from these back-calculations are liable to error, and as the distance between individual annuli is so small (particularly in older fish) exact "pin-pointing" of the annulus is essential. These errors on the posterior part are relatively more important than on the anterior part, because the total length of the posterior part of the scale is so much shorter, so that the errors will be of greater account when the measurements on the scale are expressed in terms of fish length. Therefore the posterior annuli have been rejected as the main method of growth determination, although they are sometimes a useful adjunct to age determinations from the anterior part of the scale.

To use the anterior part of the scale for growth determination it is necessary to provide a method of correction for the allometry and for the length of the fish when the scale was laid down. A logarithmic regression equation was therefore calculated using measurements of fish length and length of the projected image of the anterior part of the scale of 77 fish ranging from 10 to 106 cm. This provides correction for both the above factors. The resulting equation was: —

$$\log_{10}F = 0{\cdot}836 + 0{\cdot}749 \log_{10}S$$

where F is the length of the fish and S the length of the projected image of the scale. A curve for correcting for allometry the back-calculations made from the anterior part of the scale was drawn from this equation. Using this curve a simple apparatus was constructed (Fig. 6) (Le Cren, 1947) and this has been found most useful in enabling rapid determinations to be made of the necessary corrections, which can be of considerable size. For example, if back-calculation by direct proportion of the rings on the anterior part of the scale of a fish of

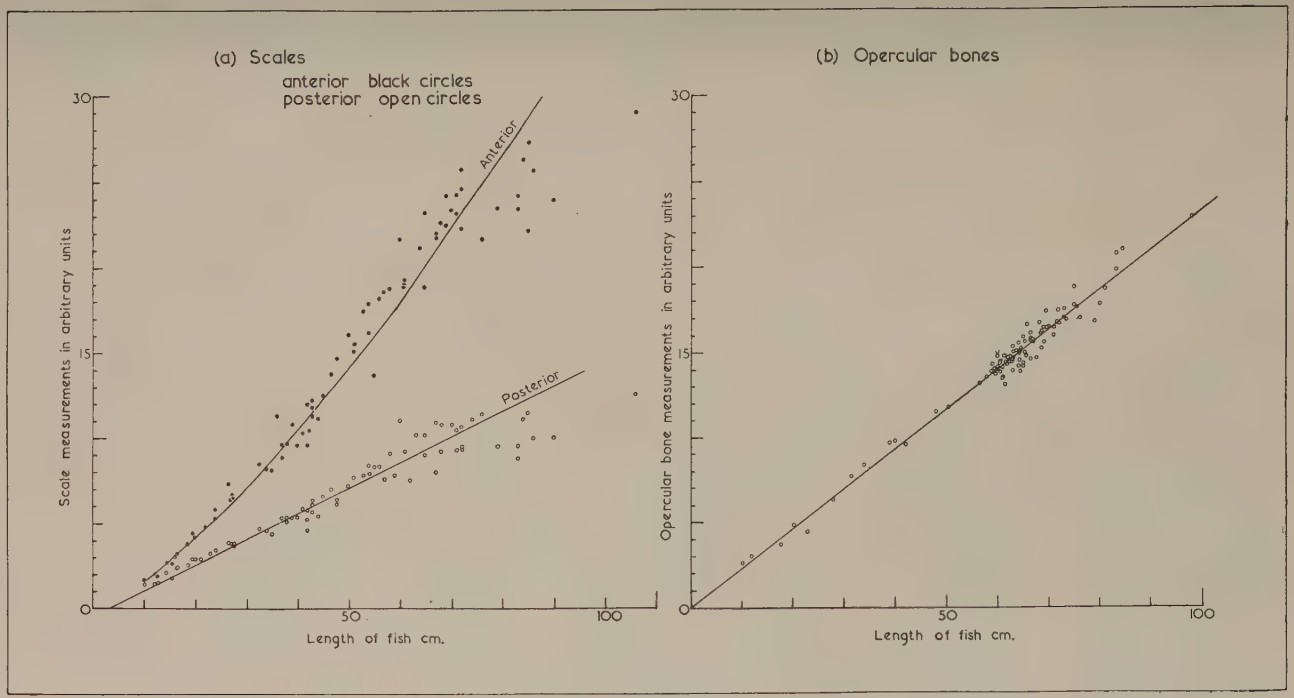

Figure 5. Tests for allometry.
(a) Scales. The plotted points for the anterior part (black circles) lie on a curve, for the posterior part (open circles) they lie on a straight line cutting the x axis at 3·5 cm.
(b) Opercular bones. The points lie on a straight line which passes through the origin.

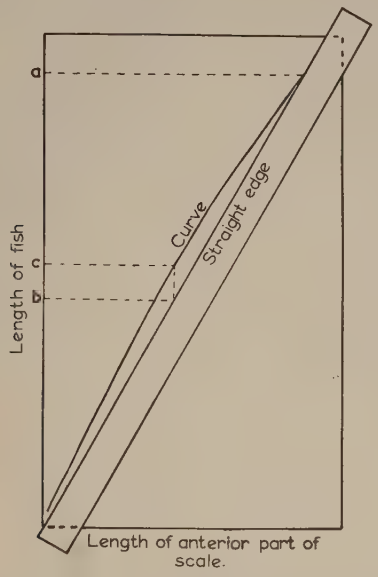

Figure 6. Diagram showing the method of correcting back-calculations for allometric growth.
a = final length of fish; b = recorded back-calculated length by direct proportion; c = correct back-calculated length.

90 cm showed the first year length to be 14 cm and second 28 cm, then the corrected values would be 22 cm and 38 cm, differences of 8 and 10 cm. All back-calculations from measurements of the anterior part of the scale have subsequently been corrected for allometry, *and all further references to scale readings automatically include correction for allometry unless the contrary is stated.*

Thus when correction for allometry has been made for readings from the anterior part of the scale, a moderately satisfactory method for determining the age and growth of the pike from its scales is available. However, as previously mentioned, there are difficulties in the use of the scale for this purpose.

Determination of age and growth from the opercular bones

Early in his study of the age and growth of perch (*Perca fluviatilis*) in Windermere, Le Cren (1947) found that opercular bones were much more satisfactory for age determinations than were scales. In view of this opercular bones as well as scales were taken from the pike of Windermere and have proved invaluable in the age and growth determination of this fish.

Determination of age and growth. On the opercular bone of fish such as perch and pike, there are "bands" which stand out because they have a different degree of whiteness from the rest of the bone (Plate 2). If these checks in the general bone structure are established as annual they give the number of years of the fish's life.

The shape of the opercular of the pike is shown in Figure 2. The bone is slightly curved, the convex and concave surfaces being the outer and inner sides of the bone respectively when it is attached to the pike. The point of attachment of the bone to the skull is seen on the concave view (Figure 2 (ii)). At this point, the centre of the bone, the opercular is thick and this thickness fans out into a spongy tissue which often becomes orange-brown and glutinous. (This rough and dense part of the bone caused much trouble since it often covered the first and sometimes the second years annuli and so obscured them, page 331). The bone shows an alternation of pattern which coincides with different types of growth. Seen by reflected light on a dark ground the opercular bone shows a broad opaque white zone (grading outwards from a milky white "line" to a more watery white area) corresponding to the rapid summer growth which passes into a narrow transparent dark zone, the winter growth, which ends abruptly with a sharp line of discontinuity between it and the next opaque zone (Plate 2a). This sharp line marking the end of the winter's growth is taken as the end of a year's growth and accepted as the annulus. In practice the bone is magnified and read by transmitted artificial light (which alters the "colour" of the two zones) (Plate 2b). These conditions make it easier to locate the boundary of the annulus precisely, although this, under any circumstances, is usually much better defined on the bone than on the scale.

Evidence that the zones of different growth pattern are annual is available from four sources: —

(1) Small fish. The opercular bones of small pike of less than 20 cm caught in Windermere between May and November in no case had an annulus. Evidence will be presented later (page 331) that such fish are almost certainly under one year-old. Therefore if any of them *had* shown a ring the annual character of such a check would be disproved.

(2) The opercular bone of the one pike reared in an aquarium (Plate 2c) and known to be 1 + years showed one annulus on the bone (and some plus growth).

(3) The growing edge of the opercular bones taken at different seasons of the year was examined. Those taken in summer and autumn had an opaque white zone at the edge whereas in winter and spring (until April-May) there was a transparent dark zone on the edge. This alternation of the two types completed the annual cycle.

For testing the annual character of the checks on the opercular data were used from those fish tagged in early spring, (thus avoiding the complication of plus growth) and recaptured after exactly one or two years absence. The lengths of all tagged pike were recorded at the time of tagging and again on recovery. If the length obtained from back-calculation to the outermost ring on the bone (i.e., that nearest to the edge) or the next but one for two years absence, tallies with the measurement of the fish when tagged, it may be concluded that the check is of annual occurrence (Plate 2g). This has been found to be so (Table 2) for it can be seen that for each fish the relevant reading from the opercular agrees reasonably well with the actual measurement at time of tagging.

Operculars, like scales, may show false annuli (Plate 2h). These are usually recognizable because they show as an abrupt instead of a gradual change or fading out from the opaque to the thin transparent zone. This characteristic is easier to pick out in the early years with their rapid growth than in the later years of slow growth so that recent false annuli are less likely to be detected

Table 2

Comparison of actual measurements and back-calculated lengths (cm) for seven tagged pike recaptured after (a) one year's absence (b) two years' absence

(a) One year's absence

Fish Log No.	P 210 (97)			P 223 (23)			P 238 (10)			P 217 (137)			
Age	1	2	3	1	2	3	1	2	3	1	2	3	4
Actual measurements on tagging and recapture	–	43·4	53·7	–	42·2	53·3	–	44·1	51·4	–	–	49·0	54·6
Back-calculated from opercular	(26)	42·8	–	25·3	43·5	–	26·0	44·5	–	19·7	34·3	48·9	–
Corrected back-calculation from scales:—													
collected on tagging	24·6	–	–	24·5	–	–	27·2	–	–	21·5	35·4	–	–
collected on recapture	23·0	42·8	–	27·8	44·0	–	27·5	44·2	–	22·7	36·0	50·5	–
Uncorrected back-calculation from scales:—													
collected on tagging	20·0	–	–	20·3	–	–	22·9	–	–	16·1	31·6	–	–
collected on recapture	17·0	39·1	–	22·2	41·0	–	22·2	42·1	–	16·8	31·0	48·7	–

Fish Log No.	P 237 (133)						P 237 (157)						
Age	1	2	3	4	5	6	1	2	3	4	5	6	7
Actual measurements on tagging and recapture	–	–	–	–	63·5	67·2	–	–	–	–	–	66·6	68·3
Back-calculated from opercular	(21)	(36)	47·0	57·3	62·0	–	(22)	35·8	52·3	58·8	63·2	66·8	–
Corrected back-calculation from scales:—													
collected on tagging	19·5	36·4	49·5	60·5	–	–	22·0	36·0	51·7	59·0	63·0	–	–
collected on recapture	19·5	38·8	52·8	61·5	64·0	–	19·8	35·2	52·2	59·6	63·0	67·0	–
Uncorrected back-calculation from scales:—													
collected on tagging	13·0	30·0	45·8	59·1	–	–	15·5	29·2	47·7	57·0	61·7	–	–
collected on recapture	12·8	32·0	48·7	59·5	63·2	–	13·0	28·0	47·8	56·8	61·9	66·3	–

(b) Two years absence

Fish Log No.	P 237 (75)							
Age	1	2	3	4	5	6	7	8
Actual measurements on tagging and recapture (twice)	–	–	–	–	–	62·5	65·0	66·0
Back-calculated from opercular	(19)	33·4	45·7	52·8	58·5	62·2	63·8	–
Corrected back-calculation from scales:—								
collected on tagging	21·2	34·7	46·5	53·4	60·0	–	–	–
collected on 1st recapture	21·8	36·0	47·0	55·0	60·5	64·0	–	–
collected on 2nd (final) recapture	22·5	35·2	46·5	54·3	60·6	63·6	65·0	–
Uncorrected back-calculation from scales:—								
collected on tagging	14·7	28·1	42·2	51·0	59·0	–	–	–
collected on 1st recapture	15·0	29·8	42·6	52·3	59·0	63·4	–	–
collected on 2nd (final) recapture	15·8	28·5	41·5	50·9	59·0	62·8	64·4	–

Figures in parentheses are estimates from the theoretical growth table.

in older fish. As with scales a false check may be suspected on the bone if a growth increment is markedly different from that found in similar fish.

From examination of the character of the edge of the opercular bone it is difficult to determine the exact date of annulus formation because the annulus is a line of discontinuity between winter and summer growth (p. 328) and is therefore not apparent until some summer growth (plus growth) is registered on the edge of the bone. The opercularis from some fish ranging in size from 15 to 65 cm, caught from March to June, were examined for the character of the edge of the bone which was noted as being with or without the new (plus) growth. It was found that plus growth (but only very little) was present on some of the pike caught in mid-April but on none caught earlier, and that some fish caught in mid-May had no plus growth although others caught at the same time showed a little; from mid-May onwards almost all the opercularis had plus growth at the edge. These observations indicate that the annulus on the opercular is probably formed in early May, at much the same time as on the scales (p. 323).

Determination of growth. To use the opercularis for back-calculation of length it was necessary to decide on the correct centre or origin of growth of the bone from which to measure these annual increments. Unlike the bone of the perch (Le Cren, 1947) that of the pike has no "hole" near its articulating surface to help to fix the origin of growth, so that an arbitrary point which appeared to be the origin of growth was chosen. On looking at the concave (the inner) face of the bone the articulating concavity can be seen (Fig. 2 (ii)) and the centre of this was taken to be the origin of growth. But because of the thickness of the articulating surface this centre is hidden when the bone is projected therefore its position has to be determined indirectly thus:— The projected bone has an outline as in Figure 2 (i) and it was found that the mid-point of a line drawn from the indentations 'b' and 'c' on this outline coincided with the accepted origin of growth of the bone, 'a' on Figure 2 (ii) on the articulating surface. The good agreement found between back-calculations as measured from this point and the observed measurements obtained from recaptured tagged fish justifies this arbitrarily chosen point as a satisfactory centre for measurement of the annual increments in growth.

Before it is justifiable to back-calculate the growth of the pike from the opercular it is also necessary, as it was with scales, to find the true proportional relationship between the growth of the opercular and the fish throughout their life. The projected images of the opercularis from fish ranging in size from 10 to 98 cm were measured on the back-calculation cardboard strips. The measurement was made from the chosen centre to the posterior edge of the bone, along the line shown in Figure 2 (i). When these measurements were plotted against the lengths of the individual fish from which they were taken it was found, by eye, that the points lay on a straight line passing through the origin, showing that the bone grows in direct proportion to the fish throughout life (Figure 5 (b)). As a further check a regression line was calculated on the same data and it gave the same results. It follows that the growth made by the fish can be calculated directly from measurements made to the annual rings on the bone without any correction for allometry or for the length of the fish when the bone was formed. The main support for the foregoing conclusions concerning the annual character of the check, the choice of the centre of the bone, the isometry of growth and length of fish when the bone was formed, is the incontravertible evidence from many returned marked pike, for they

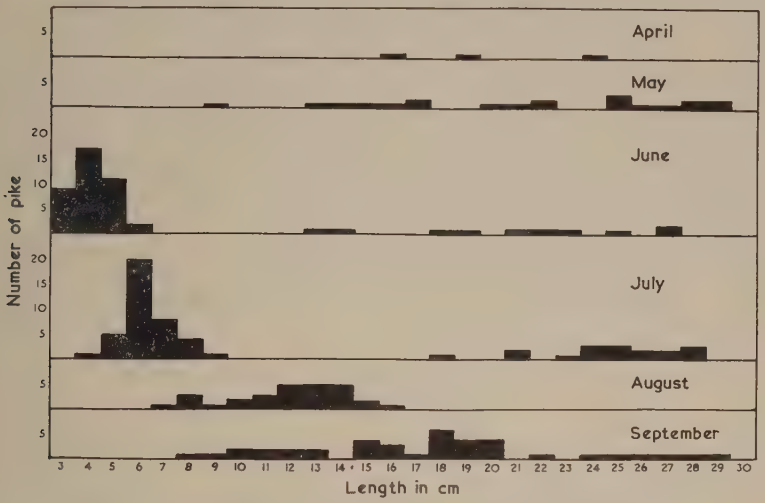

Figure 7. Length-frequency distributions of young pike of Windermere.

showed good agreement between the observed increments and those back-calculated from the operculars.

Thus the evidence given in the foregoing paragraphs justifies the use of opercular bones for determination of age and growth of the pike. But this usage still presents problems. The operculars of some fish of over about 65 cm are rather thickened throughout so that it is difficult to find the annuli, particularly those near the edge of such bones, so that an error in the ageing of the fish can be made. But the main problem associated with reading operculars is the difficulty which arises from the thickening and discolouration at the base of the bone since this can obliterate the early annuli. This presents the problem of the "missing first years". Of the hundreds of opercular bones collected from pike of Windermere about a quarter come from smaller fish. On the whole the operculars of these smaller pike (10–45 cm) are reasonably easy to read because the tissue at the base of the bone is not so dense and discoloured as to obscure the first annulus (Plate 2f). The majority of the pike, however, are larger specimens from 50–110 cm. These larger fish usually, but not always, have the base of the bone so much thickened that the first annulus (at least) is obscured so that the age read may be incorrect. Apart from this difficulty of missing first years the opercular bone presents a more satisfactory structure than the scale for reading the age of the pike and it is especially so for back-calculation of growth because the boundary of the annulus is much clearer, and therefore can be more accurately "pin-pointed", on the bone than on the scale (p. 324).

For estimating whether early rings are missing a knowledge of the length distribution of pike in Windermere at the end of the first and second year's growth is obviously essential. That wide variations can be expected is apparent from the work of Carbine (1945) on growth potential of northern pike (*Esox lucius*) in America. Three different methods have been used in an attempt to find these length distributions:—

(a) Direct observation of small fish. For several successive years small pike

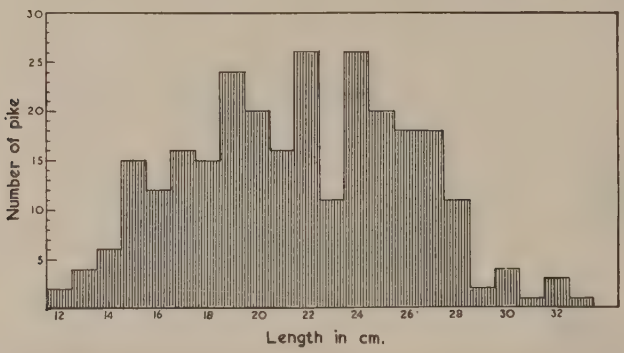

Figure 8. Frequency distribution of lengths at age 1 back-calculated from the scales of 271 pike.

were caught in weed beds and shallow bays of Windermere from April onwards. The monthly length distributions of these fish are given in Figure 7. It is possible that these samples give an underestimate of the mean length of all the fish in their first year as the quicker growing larger fish may quit the shallow waters before the end of the summer leaving mainly the smaller specimens in the area sampled. The growth of the 0 + age-group can be clearly followed from June through the early months of life, and by September the distribution has a mode of 18 cm, though, as stated above, this may be an underestimate and also some further growth may occur before they are age 1 in the next spring. The slowest growth of the fish-of-the-year here recorded is that of a fish of 8 cm caught in September, though there is no reason to suppose that this was necessarily the smallest of this age-group.

(b) Length-frequency distribution of back-calculations from scales (Figure 8). A length-frequency distribution of 271 first year lengths was derived from back-calculations from scales. The fish were caught over several years and by several methods, and males and females have not been separated. The largest was 33 cm, the smallest 12 cm, and the mean 21·6 cm (standard deviation 4·4 cm).

(c) Walford plots (p. 317) on data from tagged returned fish. Actual measurements of tagged pike recaptured after intervals of exactly one year were used. (It may be noted that for this purpose it does not matter at what time of year the fish were taken, provided the interval between the measurements was exactly one year.) These data were plotted in the manner described on p. 317 for 36 males and 21 females separately. The points for each lay approximately on straight lines cutting the diagonals at 75 and 100 cm, respectively. When these lines were projected to cut the y axis for estimates of length at age 1 the result for males was 20 cm and for females 21 cm. From the plots the fastest growing fish were estimated to have reached about 35 cm by the end of the first year.

These three different methods, two of them based entirely on actual measurements, yield very similar estimates of the mean length attained by pike in Windermere at the end of the first year of life. The lengths approximately range from 11 cm to 35 cm with a mean of about 21 cm.

The length distribution at the end of the second year's growth has also been

Table 3

Theoretical growth of Windermere pike

Calculated from Ford's formula assuming:—

1. Ultimate lengths ..... females ..... 100 cm
   males ..... 75 cm
2. Lengths at end of first year ..... slow growers ..... 15 cm
   medium growers ..... 20 cm
   fast growers ..... 25 cm
   very fast growers ..... 30 cm

Females

Age	Length in cm				Increment in cm			
	Slow	Medium	Fast	Very fast	Slow	Medium	Fast	Very fast
1	15	20	25	30	15	20	25	30
2	28	36	44	51	13	16	19	21
3	39	49	58	66	11	13	14	15
4	48	59	68	76	9	10	10	10
5	56	67	76	83	8	8	8	7
6	62	74	82	88	6	7	6	5
7	68	79	87	92	6	5	5	4

Males

1	15	20	25	30	15	20	25	30
2	27	35	42	48	12	15	17	18
3	37	45	53	59	10	10	11	11
4	44	53	60	65	7	8	7	6
5	50	59	65	69	6	6	5	4
6	55	63	68	72	5	4	3	3
7	59	66	71	73	4	3	3	1

calculated by methods (b) and (c). For the Walford plots data were used from tagged fish which had been absent exactly two years. (Figure 3 (d)). The two methods both gave a mean length of about 38 cm and a range of about 25 cm to 50 cm.

From these results it is plain that there must be some overlap of age-group I and II in particular between 25 cm to 35 cm and occasionally down to about 20 cm, that is some fish will be age 1 and some age 2 between these lengths. This was confirmed by ageing, from both scales and operculars, 18 fish of lengths 24–30 cm caught in perch traps in early spring, 12 of these were aged 1 and 6 aged 2. Therefore it is not possible to say with certainty to which age-group a particular fish belongs between these lengths, for example if back-calculation to the first visible annulus of the opercular gives a length of 30 cm this might be either the first or second annulus depending on whether the fish was a fast or slow grower, in other words, for such fish age cannot be determined without reference to growth. A simple statement of a limit below which all fish can be expected to be age 1 is therefore not possible. It should here be stressed that it is the older fish which are likely to have missing early rings but their growth increments in the later years can be back-calculated, although the age will not be known owing to doubt about the early years. If from these later increments it is possible to find out whether the fish is a fast (or medium, or slow) grower, then it would be possible to estimate the number of the missing early rings with greater accuracy. To make use of later increments to give this greater accuracy theoretical growth tables for pike of Windermere have been calculated from Ford's formula, they could also have been derived

from Walford plots, (Fig. 3 (a)). The results are shown in Table 3. These tables have been derived from the basic assumptions of "length at age 1" and "ultimate length". They have been calculated for slow, medium, fast, and very fast growers, males and females separately. From the results obtained on p. 332 fish which reached 15 cm, 20 cm, 25 cm, and 30 cm at the end of their first year were arbitrarily considered to be slow, medium, fast, and very fast growers respectively. After inspection of many Walford plots and study of the length distributions of fish caught in the past the ultimate length of males was taken to be 75 cm and of females 100 cm. These lengths are based on pike caught in Windermere in the last fifteen years, and must not be assumed to apply to other environments. These tables are therefore not necessarily valid for other waters.

The method evolved for determining age and growth from opercular bones using the theoretical growth tables is as follows. The bones are read and back-calculations made in the usual manner. Then as it is known that the first or more annuli may have been missed owing to the thickening of the bone at the centre, particularly in older fish, the growth as calculated for each individual fish is compared with the theoretical tables and a decision made as to which category the fish belongs. For example a female pike, whose innermost visible annulus on the opercular gave a back-calculated length of 48 cm, could have been at this length an exceptionally fast growing 2 year-old, or a medium 3 year-old, or a slow 4 year-old. If during the following year it had put on an increment of 10 cm from 48 to 58 cm it was probably a fish of medium growth, and therefore had the first two annuli missing on the bone. Alternatively if its increment had been 15 cm and it grew from 48 to 63 cm it was probably a fast grower and therefore only one annulus had been missed. In all cases confirmation would be sought by finding out whether slow or fast growth had been maintained throughout the rest of its life. Identical results could of course be obtained by making Walford plots for each individual fish; the theoretical tables merely provide a quicker and more convenient method of dealing with large numbers of fish. When theoretical tables are not available the procedure for Walford plots is as follows for each individual fish. The back-calculated lengths are plotted in pairs (length at age n, length at age $n+1$) as described on p. 317. A line is fitted by eye to the plotted points and extended to cut the y axis: the intercept gives the length at age 1. If this corresponds to the smallest back-calculated length obtained then no annuli have been missed. If not, then length at age 2 ($= n+1$) is found from the plot using the length at age 1 just found from the y axis intercept. If this length at age 2 corresponds with the smallest back-calculated length then one annulus has been missed (Figure 3 (c)). Again if not, then length at age 3 can be found from the plot, if this corresponds with the smallest back-calculated length then two annuli have been missed.

Obviously this individual plotting takes much time if many fish are involved. If there are more than about fifty it would probably be worth while to calculate theoretical growth tables for the particular water.

When the number (if any) of missing annuli has been found then the missing lengths attained at these annuli can be estimated from theoretical tables or from the individual Walford plots, although it is obvious that these estimates will be liable to some error, owing to the assumptions on which they are based. In the above example the estimates of the missing first and second year lengths, if it were a fish of medium growth, would be 20 and 35 cm. If it is intended to calculate mean growth from a collection of operculars then those

Table 4

Comparison of means of back-calculations of length (cm) made from the scales and operculars of 47 male pike, mean length at capture 57·7 cm

	Age 1			Age 2	Age 3
	Annulus visible on opercular	Annulus missing on opercular	Total	Annulus visible on opercular	Annulus visible on opercular
	35 fish	12 fish	47 fish	47 fish	47 fish
Uncorrected scales ..	17·5	14·9	16·8	35·3	49·6
Corrected scales	23·5	21·0	22·9	39·9	51·8
Opercular	23·1	20·9[1])	22·5	39·1	51·3

[1]) Mean of individual estimates from theoretical growth table.

The differences between the means derived from corrected scale readings and the means derived from operculars are in no case significant. Fish with early annuli visible are faster growing than those with annuli missing.

Table 5

Comparison of means of back-calculated lengths (cm) of fish with annuli visible and annuli missing on the opercular, based on pike aged 5 years and over caught in gill nets 1946–1947

	Age 1			Age 2		
	Annulus visible	Annulus missing	Total	Annulus visible	Annulus missing	Total
	27 fish	27 fish	54 fish	50 fish	4 fish	54 fish
Males.....	24·4	21·6[1])	23·0	40·2	31·8[1])	39·6
	13 fish	49 fish	62 fish	56 fish	6 fish	62 fish
Females.....	25·6	21·2[1])	22·1	39·0	35·4[1])	38·7

[1]) Mean of individual estimates from theoretical growth table.

Fish with early annuli visible are faster growing than those with early annuli missing.

bones with missing annuli must not be ignored (just because they are difficult) for their omission would produce a definitely biased mean since it is the slower growing fish which are more likely to have the missing annuli (Tables 4 and 5). It has been found that few fish under the age of 4 have missing annuli while over the age of 7 almost all have at least one missing. Two is the maximum number of missing annuli so far discovered.

The theoretical tables or individual Walford plots can also be used as a guide to check for possible false annuli (p. 328). If the back-calculated lengths do not reasonably relate to the lengths deduced theoretically it is possible that there might have been an error in reading either the age or the increments and a further check, perhaps using scales, is advisable. We have found for the pike of Windermere that this is not likely to be necessary for fish of less than 65 cm.

Tests of Validity of Methods

The validity of these methods of determining age and growth from scales and operculars of pike has been tested in various ways and the results are here briefly summarized.

(a) Agreement was in general good between observed measurements of fish at the time of tagging and lengths back-calculated to this time from operculars

Table 6

Mean back-calculated lengths (cm) at the end of each year of life of 74 male and 116 female pike caught in gill nets, 1946–1947

	Age at capture	Number of fish		Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number of theoretical estimates Age 1	Age 2
Males	2	1		29·4	44·5															
	3	1		19·0	40·6	51·5													4	
	4	18		23·2	41·0	54·6	60·1												10	
	5	21		24·1	41·3	52·7	60·8	64·4											8	1
	6	20		22·7	39·9	51·5	58·7	64·2	66·6										4	1
	7	5		21·0	36·4	48·5	55·4	60·7	64·5	66·3									1	
	8	4		25·0	38·5	51·4	56·4	61·0	64·3	67·5	69·3								1	1
	11	1		20·1	35·2	44·5	53·4	59·9	64·3	67·4	71·0	73·8	76·5	77·5					2	1
	12	2		19·1	33·2	44·8	54·4	58·9	61·9	64·4	66·4	67·9	69·4	71·0	72·5				1	
	15	1		21·1	36·7	47·3	52·2	55·2	57·9	59·9	62·2	64·4	66·6	68·2	69·9	71·3	72·5	73·5	31	4
		74	Mean	23·1	40·0	52·1	59·1	63·3	65·4	66·0	68·0	68·4	70·4	72·0	71·5	71·3	72·5	73·5		
Females	2	1		27·1	47·5														1	
	3	9		29·2	49·3	61·3													26	
	4	44		22·3	39·3	56·4	66·0												23	
	5	30		21·7	38·0	53·6	63·6	69·3											9	1
	6	12		21·8	37·9	53·0	63·2	70·8	76·2										3	1
	7	3		20·1	36·2	50·4	58·7	65·1	70·2	73·8									4	
	8	6		25·3	43·2	56·8	65·2	71·7	76·9	81·3	84·3								3	1
	10	3		23·4	41·5	56·3	66·0	72·7	78·4	82·4	85·7	88·8	90·8						2	
	11	2		21·1	38·7	51·8	61·8	68·8	73·9	77·4	80·9	83·4	85·9	87·5					4	2
	12	5		23·3	39·8	53·1	61·7	69·3	75·8	80·6	85·0	88·2	91·1	93·9	95·5				1	1
	14	1		21·1	37·2	49·8	62·3	69·3	75·8	80·4	85·4	91·3	94·7	97·5	100·4	101·7	102·5			
		116	Mean	22·7	39·9	55·3	64·4	69·8	75·7	79·7	84·4	87·8	90·4	92·8	96·3	101·7	102·5		76	6

Table 7

Comparison of back-calculated growth from operculars and theoretical growth

	Length (cm) at age				
	1	2	3	4	5
Males					
Back-calculated growth of 54 male pike aged 5 and over caught in gill nets 1946–47	23·0	39·6	51·2	58·6	63·3
Theoretical growth of fish reaching 23 cm in the first year assuming an ultimate length of 75 cm.	(23)	38·9	50·0	57·7	63·0
Females					
Back-calculated growth of 62 female pike aged 5 and over caught in gill nets 1946–47	22·1	38·7	53·6	63·4	69·8
Theoretical growth of fish reaching 22 cm in the first year assuming an ultimate length of 100 cm.	(22)	39·2	52·5	63·0	71·1

and scales (corrected for allometry) taken when the fish was recaptured subsequently. For 42 fish which had been tagged and recaptured the differences between observed mean and the means back-calculated both from opercular and scale were not significant. (Observed mean at time of tagging 47·0 cm, mean back-calculated from scales (corrected) 47·8 cm, from operculars 46·2 cm. Observed mean at time of recapture 64·1 cm.) For individual differences (absolute values i. e., ignoring sign) between observed and calculated lengths the mean was 1·5 cm for scale readings (corrected) and 1·0 cm for opercular readings. The maximum difference for an individual fish was 4·4 cm for scale readings (corrected) and 3·3 cm for opercular readings. Table 2 gives full details of those 7 of the 42 fish which were recaught after exactly one or two years and had been tagged in early spring at the end of a year's growth. It can be seen that the observed measurements on tagging agree well with back-calculations to that time, for example P 210 (97) measured 43·4 cm at time of tagging, and back-calculation from both opercular and scales (corrected) showed 42·8 cm.

(b) Agreement was good between the means of scale readings (corrected) and opercular readings; none of the differences between these values shown in Table 4 is significant. Although the means are satisfactory, individual differences between scale readings (corrected) and opercular readings can be considerable. For example in Table 2 the length of P 237 (133) at age 3 back-calculated from the opercular was 47·0 cm and back-calculated from the scale (corrected) taken at recapture was 52·8 cm.

(c) Scale readings uncorrected for allometry were unsatisfactory, (Tables 2 and 4).

(d) Those fish which had the early annuli visible on the opercular were faster growing than those which had missing annuli, (Tables 4 and 5). It follows that omission of those with missing annuli would give a biased estimate of the growth of the population.

(e) Agreement was very good between theoretical growth and growth back-calculated from operculars, (Table 7 and Fig. 3 (c)). Therefore it appears that at least in the early years of life the method of calculating theoretical growth

is adequate to describe actual growth, assuming always that the environment remains reasonably constant.

(f) When opercular were read more than once the separate results agreed closely. The second reading was in some cases made three years after the first, and in some cases by a different person.

(g) The back-calculated mean lengths at ages 1 and 2 shown in Tables 2, 4, 5, and 6 are in general agreement with those found by Walford plots using observed measurements of returned tagged fish, and also with directly observed measurements of young fish (p. 331 and Figures 7 and 8).

(h) Table 6 shows the calculated mean lengths at the end of each year of life of all the pike caught in gill nets during the season 1946–1947. The results are consistent. The back-calculated mean lengths of those age-groups containing more than six fish provide some evidence of Lee's phenomenon, which is almost certainly due to gill-net selection of those particular age-groups.

We conclude that opercular bones can be used to determine the age and growth of pike satisfactorily, and that they are preferable to scales for this purpose. Therefore it is our present practice to use the opercular bones and to turn to scales only when the opercular bone readings are difficult to interpret.

Acknowledgements

We are much indebted to our colleague Mr. E. D. Le Cren for his suggestion that Walford plots might be useful in solving the problem of the missing annuli on the opercular bones, and grateful for his criticism of the manuscript.

For the diagrams and plates we thank Miss K. Preston and Mr. A. E. Ramsbottom.

Summary

1. The use of scales and opercular bones to determine the age and growth of the pike (*Esox lucius*) has been critically examined and the use of opercular for this purpose is described for the first time.

2. It was found that age can be determined from the annuli on both the anterior and posterior parts of the scale, but care is needed to identify and reject false annuli.

3. Correction for allometry was found to be necessary for back-calculation of growth from annuli on the anterior part of the scale. It is not necessary for the posterior part of the scale.

4. The length of the fish when the scales are laid down was found to be about 3·5 cm and correction for this is required for all the back-calculations from scales.

5. An equation describing the relationship between the length of the fish and the length of the anterior part of the scale is given for the pike of Windermere and has been used for correcting back-calculations from the anterior part of the scale both for allometry and for the length of the fish when the scales were laid down.

6. The use of scales for the back-calculation of the growth of *individual* fish was found in general to be unsatisfactory, primarily on account of the ill-defined boundary of many of the annuli. On the posterior part, in older fish, the annuli in addition may be so crowded that accurate back-calculation is impossible. Therefore readings from the annuli on the anterior part of the

scale and corrected as described above have been used in preference to readings from the posterior part, and, for *large numbers* of fish, the means of such readings agree well with means obtained by other methods.

7. The rings or annuli on the opercular bones have been found to be annual, and therefore can be used to determine age, despite the fact that early annuli may be missed owing to the thick and discoloured base of some bones, particularly of older fish. False annuli may also be present, but they are easier to identify than those on the scales.

8. Growth of the opercular bone and the fish is isometric, and also no correction is needed for the length of the fish when the bone is formed. Therefore direct proportion can be used to determine growth from the annuli on the bone. The method of finding an arbitrary "origin of growth" of the bone from which to make the back-calculations is described.

9. To overcome the difficulty of the missing early annuli on the operculars a method has been evolved using either Walford plots or calculated theoretical growth tables, which enables estimates to be made of the number of missing annuli and the lengths at these times. (Walford plots are for individual fish; identical results are obtained from the tables, which, however, provide a quicker method of dealing with many fish.)

10. Tests of validity of the methods are described, some of them based on comparisons with records of returned tagged fish.

11. It is concluded that the opercular bone provides a valid method of determining the age and growth (but not the age without the growth) of pike, and that although the scales can be satisfactory for the determination of age they are not recommended for the determination of growth.

Zusammenfassung

1. Die Verwendung der Schuppen und des Operculum für die Bestimmung des Alters und Wachstums des Hechtes (*Esox lucius*) wurde kritisch geprüft. Die Verwendung des Operculum für diesen Zweck wird zum erstenmal beschrieben.

2. Es wurde gefunden, dass das Alter sowohl nach den Ringen im vorderen wie im hinteren Abschnitt der Schuppe bestimmt werden kann, dass aber darauf geachtet werden muss, dass falsche Ringe erkannt und ausgeschieden werden.

3. Mit Rücksicht auf die Allometrie wurde für die Rückberechnung des Wachstums nach Ringen auf dem vorderen Abschnitt der Schuppe eine Korrektur für notwendig befunden; für den hinteren Abschnitt der Schuppe ist eine solche Korrektur nicht notwendig.

4. Wenn die Schuppen auftreten, hat der Fisch bereits eine Länge von 3·5 cm erreicht. Bei allen Rückberechnungen von Schuppen muss daher auch dafür eine Korrektur angewendet werden.

5. Für den Windermere-Hecht wird eine Gleichung für die Beziehung zwischen der Länge des Fisches und der Länge des Vorderabschnittes der Schuppe aufgestellt. Durch die Verwendung dieser Gleichung nach der Rückberechnung aus dem Vorderabschnitt der Schuppe ist sowohl die Allometrie wie die Fischlänge beim Auftreten der Schuppen korrigiert.

6. Die Verwendung der Schuppen zur Rückberechnung des Wachstums des *einzelnen* Fisches wurde im allgemeinen unbefriedigend gefunden, vor allem

wegen der unklaren Begrenzung der Ringe. Im hinteren Abschnitt der Schuppen stehen ausserdem die Ringe bei älteren Fischen oft so eng, dass eine sichere Rückberechnung nicht möglich ist. Deshalb wurde es vorgezogen, die Ringe des vorderen Abschnittes unter Berücksichtigung der oben erwähnten Korrektur zu verwenden. Die Mittelwerte solcher Berechnungen stimmen mit den Mittelwerten aus anderen Methoden gut überein, wenn sie von einer *grossen Anzahl* von Fischen gewonnen werden.

7. Die Ringe auf dem Operculum haben sich als Jahresringe erwiesen und können daher für die Altersbestimmung verwendet werden, wenn auch die ersten Ringe wegen der dicken und verfärbten Basis mancher Opercula besonders älterer Fische fehlen können. Es können auch auf dem Operculum falsche Ringe vorhanden sein, aber sie sind hier leichter als solche zu erkennen als bei den Schuppen.

8. Das Wachstum des Operculum und des Fisches ist isometrisch. Eine Korrektur der Fischlänge beim Auftreten des Operculum ist nicht nötig. Daher kann das Wachstum nach dem Operculum direkt berechnet werden. Es wird eine Methode beschrieben, einen "Beginn des Wachstums" des Operculum für die Rückberechnung des Wachstums willkürlich festzulegen.

9. Um die Schwierigkeit des häufigen Fehlens der ersten Ringe auf dem Operculum zu überwinden, wurde unter Verwendung von Walford-Diagrammen oder theoretisch berechneten Wachstumstabellen eine Methode entwickelt, die die Schätzung der Zahl der fehlenden Ringe und der ihnen entsprechenden Längen ermöglicht. (Das Walford-Diagramm ist für Einzelfische gut anwendbar. Die Tabellen bringen dieselben Resultate, ermöglichen aber die schnellere Bearbeitung einer grösseren Anzahl von Fischen.)

10. Es werden Tests auf die Genauigkeit der Methoden beschrieben, die zum Teil auf den Vergleich mit Ergebnissen von markierten Fischen basiert sind.

11. Aus den Ergebnissen der vorliegenden Untersuchungen wird geschlossen, dass das Operculum eine gute Methode für die Bestimmung des Alters und Wachstums des Hechtes bietet (nicht aber des Alters ohne Wachstum!) und dass die Schuppen, obwohl sie für die Altersbestimmung befriedigende Resultate liefern, für die Bestimmung des Wachstums nicht empfohlen werden können.

References

Alm, G., 1919. "Fiskeribiologiska undersökningar i sjöarna Toften, Testen och Teen. (Nericke)". Medd. Landtbr.-Styr. Stockh., No. 218.

Alm, G., 1921. "Undersökningar över tillväxt och föda hos Klotentjärnarnas fiskarter". Medd. Landtbr.-Styr. Stockh., No. 232: 119–44.

von Bertalanffy, L., 1957. "Quantitative laws in metabolism and growth". Quart. Rev. Biol., **32**: 217–31.

Carbine, W. F., 1945. "Growth potential of the northern pike (*Esox lucius*)". Pap. Mich. Acad. Sci., **30**: 205–20.

van Engel, W. A., 1940. "The rate of growth of the northern pike, *Esox lucius* Linnaeus, in Wisconsin waters". Copeia, 1940: 177–88.

Ford, E., 1933. "An account of the herring investigations conducted at Plymouth during the years from 1924 to 1933". J. Mar. biol. Ass. U.K., **19**: 305–84.

Frost, W. E., 1954. "The food of pike, *Esox lucius* L., in Windermere". J. anim. Ecol., **23**: 339–60.

Haakh, T., 1929. "Studien über Alter und Wachstum der Bodenseefische". Arch. Hydrobiol. (Plankt.), **20**: 214–95.

Hartley, P. H. T., 1947. "The natural history of some British freshwater fishes". Proc. zool. Soc. Lond., **117**: 126–206.
Healy, A., 1956. "Pike (*Esox lucius* L.) in three Irish lakes". Sci. Proc. roy. Dublin Soc., **27**: 51–63.
Le Cren, E. D., 1947. "The determination of the age and growth of the perch (*Perca fluviatilis*) from the opercular bone". J. anim. Ecol., **16**: 188–204.
Lee, R. M., 1912. "An investigation into the methods of growth determination in fishes by means of scales". Publ. Circ. Cons. Explor. Mer, 63: 3–35.
Miller, R. B., & Kennedy, W. A., 1948. "Pike (*Esox lucius*), from four northern Canadian lakes". J. Fish. Res. Bd. Can., **7**: 190–99.
Munro, W. R., 1957. "The pike of Loch Choin". Sci. Invest. Freshw. Fish. Scot., 16: 16 pp.
Nilsson, D., 1921. "Några insjöfiskars ålder och tillväxt i Bottniska Viken och Mälaren". Medd. Landtbr.-Styr. Stockh., No. 231.
Oliva, O., 1956. "K biologii stiky (*Esox lucius* L.). To the biology of the pike (*Esox lucius* L.)". Mém. Soc. Zool. tchecosl., **20**: 208–23.
Rounsefell, G. A., & Everhart, W. H., 1953. "Fishery science: its methods and applications". N.Y. John Wiley. 444 pp.
Walford, L. A., 1946. "A new graphic method of describing the growth of animals". Biol. Bull. Woods Hole, **90**: 141–47.
Williams, J. E., 1955. "Determination of age from the scales of northern pike (*Esox lucius* L.)". Dissertation Abstracts, Univ. Microfilms, Ann Arbor, Mich., **15** (9): 1684. (Sport Fishery Abstracts, 1, No. 3, Abstract No. 417).

Creel Selectivity in the Capture of Lobsters and Crabs

By

H. J. Thomas

1. Introduction

Lobster and crab fishing in Scotland is undertaken almost exclusively by means of creels, the general design of which is described in "Practical hints for lobster fishermen" (Scottish Home Department, 1952). Nevertheless, local variations occur. The effect of certain modifications to the general pattern has been reported previously (Thomas, 1953). Apart from the desirability of ascertaining the optimum fishing methods, it is important to evaluate the selectivity of the gear in order to make valid assessments of the stock position and the effect of fishing. The present investigations into the selective effect of the size of the creel eye and its rig were carried out from the fishery research vessel "Kathleen" of the Scottish Home Department, working in Orkney waters during September 1954 and 1956.

Thanks are due to Mr. J. A. Pope of the Marine Laboratory, Aberdeen, for his assistance in the statistical treatment of the results.

2. Material and Methods

Double-eyed Scottish type creels, of base measurement 27 in. by 16½ in. and of height 13½ in. with a mesh netting 75 mm were used throughout the experiments. The lower halves of the creel eyes in all cases were lined by netting of 17 mm mesh. Ten variants of the inner ring of the eye were used in two series with inside diameters 4 in., 4½ in., 5 in., 5½ in., and 6 in. respectively. In one such series the eye was open whilst in the other it was fitted with a non-escape shutter of the pattern described in "Practical hints for lobster fishermen" (Scottish Home Department, 1952), except that the shutter was constructed of light-gauge wire (12 gauge British standard, 2·7 mm). Special care was taken throughout the experiments to ensure that this shutter was movable with complete freedom.

During the 1954 experiments the funnel of the eye was led horizontally into the creel (Fig. 1A). For the 1956 experiment the rig was changed, the funnel

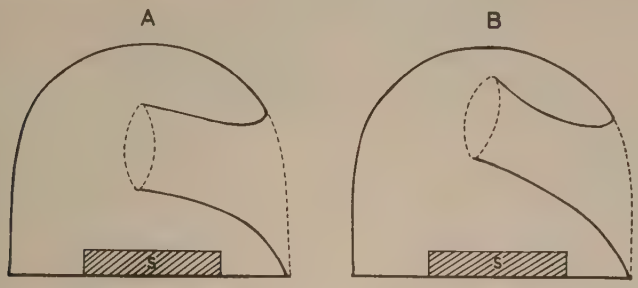

Figure 1. Cross-section of a creel (diagrammatic) showing the low (A) and the high (B) rig of eye. S, the stone sinker.

of the eye being led upwards into the creel so that the ring was positioned just beyond the mid-vertical line and sloping inwards (Fig. 1B).

Fifty creels were used, five of each eye pattern. They were shot in five fleets, each of ten creels comprising one of each eye type. The arrangement within each fleet was randomized. A separation of about 15 metres was allowed between the creels, all of which were baited similarly at any one fishing. The fleets were shot alongshore in depths of 3 to 8 metres, primarily on lobster ground, care being taken to ensure, as far as possible, that the complete fleet was at a uniform depth. The period of fishing was usually about twenty-four hours.

Lobsters caught were sexed and measured to the nearest millimetre, taking the overall length from the tip of the rostrum to the end of the telson with the tail fully extended. Crabs were measured to the nearest millimetre, taking the maximum width of the carapace. The statistical treatment of results followed the procedure employed by THOMAS (1953).

3. Results

Fishing during 1954 was undertaken with creels having lowslung eyes (Fig. 1A). The total number of lobsters caught by creel types for each fishing and overall is given in Table 1, together with the average length of lobsters caught. An analysis of variance of number of lobsters caught was carried out, the results of which indicate that the differences between the mean catches of the individual creel types are significant at the 1% level. The open creels caught significantly fewer lobsters than the shuttered creels at all sizes of eye diameter used in this experiment. The effect of increasing the eye diameter was to cause a significant linear decrease in catch for both open and shuttered creels.

An analysis of variance of size of lobster caught by the different creel types showed that this was unaffected by either the size of the eye or the type of the eye.

The corresponding data in respect of crabs, of marketable size only, is given in Table 2 and Figure 2 respectively. An analysis of variance shows that the differences between the mean catches of the individual creel types are not significant. An analysis of variance of size of crabs caught showed no evidence of real differences between open and shuttered creels but the effect of different

Table 1

Catch of lobsters per fishing and overall, together with the mean length of lobster caught, by creel types, September 1954

		Fishings															Mean length,
	Creel type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	mm
4″	Open	–	2	1	5	2	1	1	–	7	–	–	1	1	3	24	273
	Shuttered.....	1	–	–	5	2	2	3	2	4	1	4	–	1	1	26	266
4½″	Open	–	2	–	5	2	1	3	–	5	1	–	1	–	1	21	281
	Shuttered.....	–	–	–	2	2	2	3	–	8	3	2	1	1	2	26	267
5″	Open	–	–	–	5	1	2	3	1	–	1	1	–	2	1	17	274
	Shuttered.....	–	1	3	1	2	–	2	–	2	2	–	2	2	–	17	283
5½″	Open	–	–	–	1	–	1	1	–	1	–	–	–	1	1	6	261
	Shuttered.....	2	1	–	6	–	1	–	–	3	3	1	1	2	1	21	270
6″	Open	–	–	–	1	1	–	–	–	2	–	–	–	–	–	4	250
	Shuttered.....	1	–	–	–	–	1	1	–	–	–	–	1	2	1	7	288

sizes of eye diameter was significant at the 5% level. In particular the 5 in. creel caught significantly larger crabs than either the 4 in. of 4½ in. creels while the 4 in. creel caught significantly smaller sizes than all others with the exception of the 4½ in. creel.

In 1956 an identical arrangement and the same procedures were adopted as in 1954 except that the creel eyes were rigged to point well up into the creel (Fig. 1B). In the case of lobsters (Table 3, Fig. 3) the creels with the 5½ in. shuttered eyes had the biggest catch. An analysis of variance indicates that the differences between the mean catches of the individual creel types are significant at the 5% level. In all cases the shuttered eyed creels caught significantly more lobsters than the corresponding open-eyed creels. There was no evidence that different sizes of eye diameter had any effect on the number caught. On the other hand, there was evidence that the size of lobsters caught did vary significantly with size of eye, lobsters of larger average size being caught by larger eyed creels.

In the case of crabs an analysis of variance indicates that the difference between the mean catches of the individual creel type are not significant. An analysis of the sizes of crabs caught showed no significant differences between the creel types.

Table 2

Catch of crabs (marketable sizes only) per fishing and overall, together with the mean carapace width of crab caught, by creel types, September 1954

		Fishings																Mean width,
	Creel type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	mm
4″	Open	–	–	2	1	–	1	10	3	–	–	2	–	–	–	–	19	135
	Shuttered.....	3	–	–	2	1	1	2	5	–	4	1	2	–	1	–	22	129
4½″	Open	2	–	3	2	3	–	5	4	1	–	–	–	1	–	–	21	131
	Shuttered.....	1	2	1	–	3	2	6	5	1	1	2	–	–	–	–	24	140
5″	Open	4	1	3	–	4	2	11	9	4	8	1	–	–	–	1	48	145
	Shuttered.....	2	1	–	–	2	3	2	–	1	4	2	2	–	2	2	23	141
5½″	Open	1	1	1	1	3	2	9	–	–	2	1	1	1	1	–	24	139
	Shuttered.....	1	1	2	–	2	4	5	2	2	4	6	–	–	–	1	30	142
6″	Open	1	1	–	–	3	3	1	2	1	5	2	–	1	–	–	20	140
	Shuttered.....	2	1	3	1	–	2	8	7	–	4	5	–	–	2	–	35	143

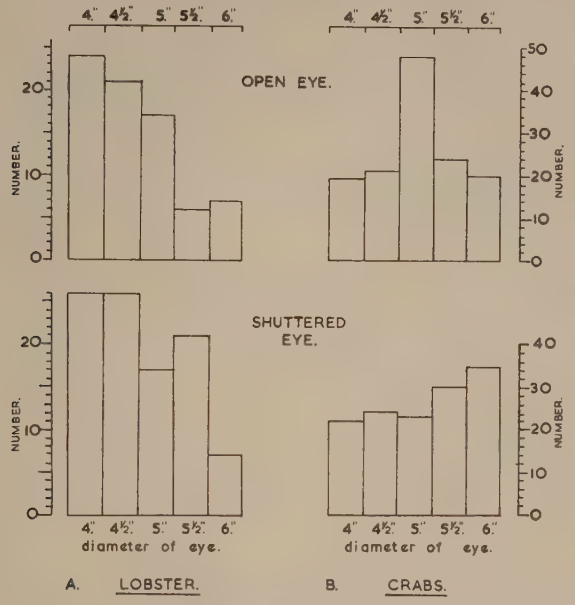

Figure 2. The catch of lobsters (A) and crabs (B) respectively by open and by shuttered eyed creels, having a low rig, at a range of eye diameters.

Whilst more lobsters and crabs were caught per creel haul using the creels with the high rig of eye (Fig. 1 B), the fact that the experiments were not carried out at the same time and place invalidates a strict comparison of the results, since the stocks fished may not have been comparable. On the other hand, the fact that similar results were obtained for both lobsters and crabs does suggest that the high rig of eye deters escape.

Is is reasonable to suppose that the wider the diameter of the eye the more readily will lobsters and crabs enter the creel and the easier will be their escape. This would tend to operate more especially in the case of smaller lobsters and crabs. The fall-off in the catch of lobsters by creels with larger diameter of open eye can be attributed principally to the greater ease of escape, although under certain conditions variations in the ease of entry and of escape through the various sizes of open creel eye may offset each other. With shuttered eyes, on the other hand, this does not apply, and creels with the wider eye diameters tend to catch a somewhat larger average size of lobster (1956) and of crabs (1954).

On three occasions in both the 1954 and 1956 experiments two fleets were left out for twenty-four hours with each creel containing a lobster. Escapes occurred from all classes of creel but more so from the open-eyed creels. Escapes from shuttered eyes may be accounted for by the fact that creels rarely lie on a horizontal bottom, and where tilted to any considerable extent, one eye is effectively open. Furthermore, in shooting the gear the wire shutter in some cases gets caught up in the mesh netting at the top of the creel, so that

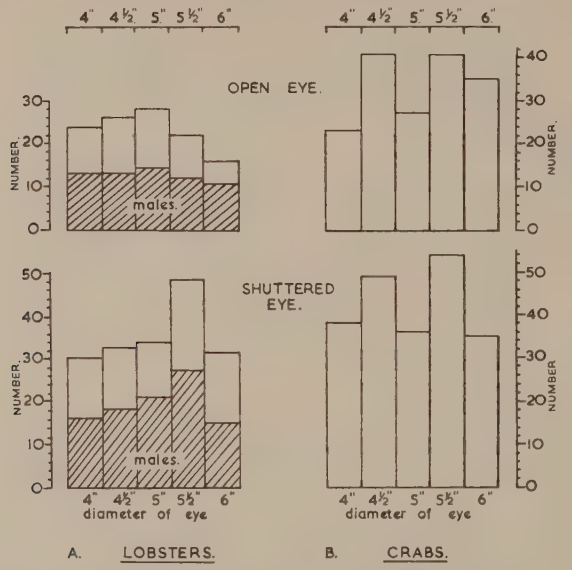

Figure 3. The catch of lobsters (A) and crabs (B) respectively by open and by shuttered eyed creels, having a high rig, at a range of eye diameters.

in these circumstances also the eye is effectively open. In the case of the 6 in. and to some extent the 5½ in. diameter eyes, some lobsters may be able to escape between or on either side of the prongs of the shutter, which cannot completely guard so wide an opening. However, in general, the shutter does, in large measure, prevent the escape of lobsters which have entered the creel. Although it may to some extent deter entry of the creel, this effect can be minimized by scrupulous attention to the free action of the shutter and the use of a light-gauge wire. Whilst creels with shuttered eyes, of all diameters, caught more lobsters than those with corresponding sizes of open eye, the difference was more marked at wider eye diameters where escape through the open eye is relatively easy.

4. Discussion

The above interpretation of the results is probably a satisfactory indication of the optimum creel type suitable for the conditions of this particular fishery at Orkney. It is not so certain to what extent they may apply under other circumstances: for instance, in an area of mixed lobster and crab fishing, or where stocks are relatively more heavily or more lightly fished. The creel with the 5½ in. diameter shuttered eyes and the high rig would, however, appear to have general advantages.

It is more difficult to decide to what extent the type of gear used biases any estimate of the density and composition of the stock. Where observations can be undertaken from research vessels using a standard gear, results between

Table 3

Catch of lobsters per fishing and overall, together with the mean length of lobster caught, by creel types, September 1956

		Fishings																	Mean length,
	Creel type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total	mm
4″	Open	1	1	2	2	–	–	–	1	1	2	4	3	2	1	1	1	2	24	271
	Shuttered	1	1	–	3	1	1	–	–	2	2	4	3	4	2	1	2	3	30	262
4½″	Open	3	3	–	2	–	–	2	2	1	–	1	1	3	2	2	2	2	26	296
	Shuttered	1	4	1	3	1	1	–	1	1	2	3	6	4	–	1	1	3	33	257
5″	Open	1	2	3	4	–	3	–	–	–	–	2	2	3	–	6	1	1	28	277
	Shuttered	–	1	5	3	1	1	–	1	2	1	4	2	3	–	5	3	2	34	276
5½″	Open	2	1	3	2	1	–	–	–	3	1	3	1	2	–	2	1	–	22	280
	Shuttered	4	3	4	4	2	2	1	5	1	2	7	2	4	–	–	2	5	48	279
6″	Open	1	–	2	4	–	1	–	–	1	–	1	2	–	–	–	3	1	16	290
	Shuttered	1	1	3	2	–	–	1	–	–	2	3	3	7	2	2	3	1	31	294

Table 4

Catch of crabs (marketable sizes only) per fishing and overall, together with the mean carapace width of crab caught, by creel types, September 1956

		Fishings																	Mean width,
	Creel type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	mm
4″	Open	1	–	1	1	1	2	3	–	–	2	1	–	1	2	6	2	23	136
	Shuttered	–	–	5	1	2	3	–	–	2	2	1	1	9	6	5	1	38	131
4½″	Open	–	–	2	2	1	4	2	1	2	1	4	7	10	1	–	4	41	137
	Shuttered	1	–	4	3	7	2	–	2	–	–	1	2	14	6	5	2	49	136
5″	Open	–	–	–	2	1	1	–	1	1	1	2	3	5	3	6	1	27	138
	Shuttered	2	2	2	3	3	3	2	–	4	–	6	–	5	3	1	–	36	140
5½″	Open	3	–	2	2	4	2	4	1	–	1	3	4	5	4	4	2	41	140
	Shuttered	–	–	3	–	6	6	–	–	1	–	8	2	12	11	3	2	54	135
6″	Open	1	1	2	–	2	6	2	–	4	1	2	3	2	6	3	–	35	135
	Shuttered	1	–	4	1	5	3	4	–	–	–	4	2	1	4	4	2	35	136

areas will be comparable, but to a large extent observations must be based on commercial landings. It is important to decide to what extent such data are valid. In the case of lobster stocks the present results as well as those previously recorded (THOMAS, 1952) suggest that area differences will be most marked where there is a high proportion of large lobsters. In an area of intensive fishing with an annual mortality rate of 70%, the stock of marketable sized lobsters (23 cm and above) will comprise fewer than 10% of individuals over 30 cm (THOMAS, 1955). The size selectivity of the creel over this narrow range of 7 cm is unlikely seriously to invalidate conclusions based on the results of commercial fishing. The variety of creel types here investigated would not appear likely to result in serious inaccuracies in the estimation of the stock position in the area of the experiments in which the annual mortality rate, in the stock of marketable lobsters, has been estimated at about 30% (THOMAS, 1955). This argument would not apply in areas of underfishing where there is a high proportion of large individuals. It must be anticipated that the duration of fishing will also have effect. In these experiments the creels were usually and as far as possible left for about twenty-four hours. Where longer periods of fishing are common

a difference in the size composition of the catch could result, especially where open-eyed creels are employed. Whilst it is desirable to be able to evaluate the effect of fishing in relation to the stocks in all areas, the inaccuracies in areas of underfishing due to creel selectivity are of less material consequence.

5. Summary

1. Rigging creels with the eye inlet running high up into the creel appears to deter escape of both lobsters and crabs.

2. The wider the eye diameter the easier is both access and escape.

3. With low-rigged creels the added facility for escape of lobsters through wider eyes results in a smaller catch. With high-rigged creels ease of entry offsets escape.

4. In the case of shuttered eyes escape is impeded and wider diameters of eye give a better result than the corresponding open eye. Nevertheless the widest eye still permits frequent escapes of lobsters resulting in a lowered catch.

5. The high-rigged creels at narrower diameters of eye catch a smaller average size of lobster than the large diameter and the effect is more marked with shuttered eyes than with open eyes.

6. The size of crabs caught in low-rigged creels is greater at wider eye diameters.

7. The significance of the above results, from the fishermen's point of view and in relation to the estimation of population statistics, is discussed.

References

Scottish Home Department, 1952. "Practical hints for lobster fishermen". pp. 16. Edinburgh: H.M.S.O.

THOMAS, H. J., 1953. "The efficiency of fishing methods employed in the capture of lobsters and crabs". J. Cons. int. Explor. Mer, **18**: 333–50.

THOMAS, H. J., 1955. "Observations on the sex ratio and mortality rates in the lobster (*Homarus vulgaris* Edw.)". J. Cons. int. Explor. Mer, **20**: 295–305.

Some Observations on the Occurrence of *Leander serratus* Pennant, in Irish Waters

By

F. A. Gibson

Fisheries Division, Department of Lands, Dublin

Fishing trials for the common prawn (*Leander serratus* Penn.), were held at Crookhaven and Bantry Bay, County Cork, in August 1955. Monthly samples of prawns were received from Bantry Bay from September 1955 to April 1956. Further experimental fishing for prawns took place in Clew Bay, County Mayo, in September and October 1955; at Creedon Head, County Waterford, in June 1956; in the estuary of the Gowla Beg River in Gortaboy Bay, County Galway, in July 1956; and at Helvick, County Waterford, in August 1956. The samples from these trials came from many varied types of fishing grounds. Crookhaven is a sheltered inlet, deeply cut by tidal guts where sand and mud alternate with rocks covered by dense growths of the brown seaweeds. Those samples from Bantry Bay came from an exposed area, where the bottom is largely formed by stones and shell. Clew Bay is a very large islet studded region, shallow and subject to much disturbance in heavy weather. The bottom here includes many areas where *Zostera* sp. is re-establishing itself, and incidentally in these patches the best catches were obtained. That part of Gortaboy Bay was chosen particularly because it is subject to a large body of fresh water entering it. The bottom at Helvick is chiefly of mud, stones, and brown seaweeds.

Creel fishing formed the basis of all experiments. Only one beam trawl experiment was undertaken (in Bantry Bay in April 1956), and this met with indifferent success. At Crookhaven in 1955 two types of creel, one of basic French design, and the other an English design were used. Both types of creel were covered by $\frac{3}{8}$ inch (9·5 mm) wire meshing, differing in that the English creel's mesh was hexagonal, whilst the French was square. The creels were fished on buoyed trot lines, and placed about 24 feet (7·3 m) apart. The bait used included waste fish, viz. Connor (*Labrus maculatus*), conger eel (*Conger vulgaris*), pollack (*Gadus pollachius*), dabs (*Limanda limanda*), green shore crab (*Carcinus maenas*), mussels (*Mytilus edulis*), hermit crab (*Eupagurus bernhardus*) and dead lobsters (*Homarus vulgaris*) (from nearby holding ponds). Salted baits

Table 1

The relationship of the mean catch of prawns to the number of live shore-crabs, in 11 creels at Crookhaven 1955

Number of live shore-crabs in creels	1–10	11–54
Mean catch of prawns.....	66·1	1·2
–	132·3	3·3
–	154·4	14·6
–	179·6	28·0
–	196·3	30·1
–	–	78·2

Table 2

Mean catch of prawns per lift at Crookhaven during August 1955

Date	English creel (9·5 mm mesh)	French creel (9·5 mm mesh)
6.	22·5	93·6
7.	33·2	94·7
8.	40·0	57·2
9.	37·0	36·3
13.	32·0	69·7
14.	29·0	76·3
15.	28·0	42·1
16.	20·0	40·4
18.	21·5	39·9

were rarely used. At Crookhaven the creels were at first fished at 05·00, 11·00, 17·00, and 22·00 hours. This produced a daily catch curve with peaks at dawn and at dusk, and such negligible catches during daylight that fishing at this time was discontinued in all subsequent experiments. Night fishing at short intervals of 30 minutes to 1 hour, was found to be very effective when the weather was calm and the tides were strongly running springs.

Bait

Various kinds of bait were used, and the result by comparison of catch figures indicated that crushed shore-crab is the most attractive animal bait. It was difficult to determine whether crushed shore-crab was more efficient because it attracted prawns, or because it discouraged live shore-crabs from entering the creels. The more live shore-crabs in a creel the fewer were the prawns in that creel's catch. Individual counts of the mean number of live shore-crabs to prawns per creel showed that prawns appeared to be more abundant in the absence of shore-crabs at the 0·001 level of significance (see Table 1).

Although these figures suggest a high degree of significance that large numbers of prawns enter the creels when there are less than 10 live shore-crabs already in the creels, no conclusion is possible that such results will always be obtained. It may be that the real significance lies in the possibility that live shore-crabs tend to avoid the presence of their own dead.

At Helvick, County Waterford, shore-crabs were difficult to obtain, and few

entered the creels at the time when fishing took place, so that the chief bait used was pollack and hermit-crab, and in this case the catch of prawns was 30% less than at Crookhaven. In Bantry in September 1955, during the first two days fishing, salted herrings were used as bait, and the catch per creel was less than 10 per lift. Subsequently, in the same area, crushed shore-crab was used, and the catch was raised to approximately 47 per lift. At Clew Bay and Gortaboy Bay shore-crab was the only bait used, and the catch of prawns per lift was 13·6 and 25·4 respectively.

Yield per Unit of Effort

The unit of effort was taken to be the lifting of a single creel. A comparison of the difference in catch numbers per lift for the English and the French creels was made at Crookhaven, when 6 of the former were fished against 12 of the latter in randomly selected positions on one trot line. The mean daily yield per lift over 9 days is shown in Table 2.

These results give a value for t of 3·95 which is significant at the 0·01 level. Apart from the strong suggestion that the French creels are more efficient, it was found in practice that they were quicker to haul, fish, and bait and easier to stow. French creels were therefore used in all subsequent experiments.

The mean yield per lift for all experiments is shown below in Table 3.

The yield per creel varied greatly with each fishing and in each area, even when all creels had been baited similarly. It was not unusual to find that from 10% to 20% of the creels on occasion yielded no prawns, whilst others on the same trot line had yielded as many as 175 prawns. When shooting a trot line it is not always possible to choose the desired patch of sea-bottom, and in consequence blank lifts may be caused when the creels fall into and become completely covered by weed.

The yield per lift figures whilst not as high as they might be, are nevertheless taken over good and bad fishing grounds and weather conditions, and at best represent approximately 250 g weight of prawns per lift per day. The yield at Crookhaven was good, and this is put down to the ideal nature of the grounds there. Although the Bantry Bay figures are somewhat less than those of Crookhaven, they may, over a longer period represent a much higher yield because this area has a consistent yield except in the months of March, April, May, and June. The Clew Bay mean yield was very low because so much broken weather interfered with the fishing. It is noteworthy that a fishing on *Zostera* beds near

Table 3

Mean yield per lift for French and English creels in all experiments

Place		French creel	English creel
Crookhaven	1955	60·02	29·27
Bantry	1955[1])	46·98	–
Clew Bay.....	1955	13·60	–
Creedon Head	1956[1])	–	–
Gowla Beg	1956	25·40	–
Helvick	1956	43·20	–

[1]) Excluding salt bait catch figures, and Dunmore East material.

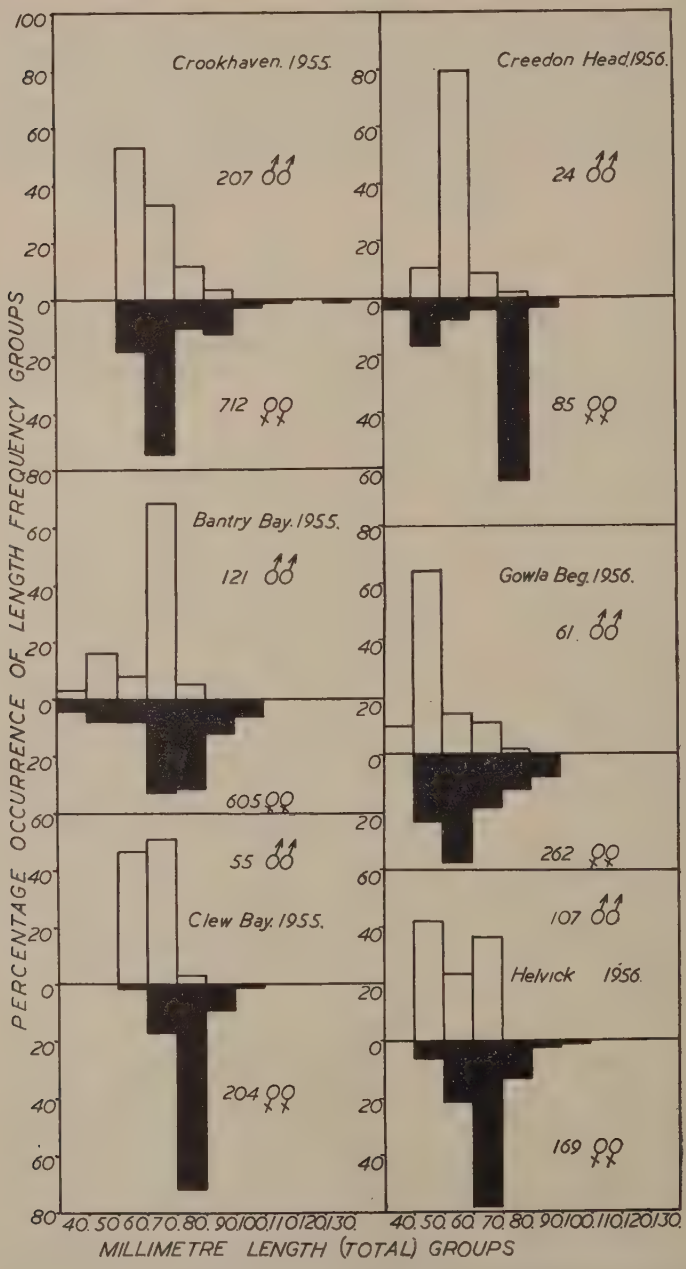

Figure 1. Ratio of male to female prawns, together with frequency distributions of both sexes in the various areas fished in 1955 and 1956.

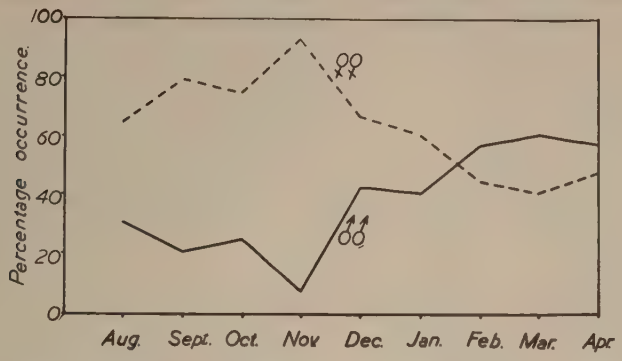

Figure 2. Percentage occurrence of male and female prawns in Bantry Bay material from August 1955 to April 1956.

Friar's Island, Clew Bay, yielded 55 prawns per lift. The Gortaboy yields were small, and the possible influences of fresh water are suggested. The Helvick yields were made, incidental to Norway lobster fishing trials, when it was not possible therefore to lift the creels regularly, and shore-crab was not common as bait. A creel with a 6·4 mm square mesh cover fished both at Gortaboy Bay and Helvick reduced the mean length of the catch as taken with the 9·5 mm mesh, by approximately 6·6 mm. Escapement from creels is believed to be high. In a confined pool of clear water, a creel containing 50 prawns and baited with shore-crab was observed. The prawns appeared to escape and re-enter the creel, with apparent ease and indifference. Escape was almost invariably made by passing the tail and abdomen first through the 9·5 mm mesh and re-entry was as often through the creel mesh as by the eye.

Analysis of Catch

A sample of the daily catch in each area was mechanically segregated, so as to avoid as much as possible the bias of hand selection. Each sample was examined for length and sex. The histograms in Figure 1 are based on the relationship of the total length of the prawns to the length of the carapace measured from the base of the eye to the nearest point on the margin of the carapace. Males were found to be consistently smaller than females. Only one male was ever obtained which measured more than 100 mm. The great majority of the prawns captured lay within the size range between 60 to 80 mm. The average weight of the prawns in this size distribution was found to be approximately 250 to the kilogramme.

In Figure 2, the ratio of males to females for the Bantry Bay samples from August 1955 to April 1956 shows that the percentage of males increased from November until a maximum was reached in March. Over the same period the number of berried females (Figure 3) rapidly increased until February, after which there was a sudden decrease in their incidence, suggesting that shedding had largely taken place in February or in March. From November until February the fishing grounds in this part of the bay are entirely located on an area known as the "Quay". The Quay is a large area of loose strewn, old red sand-

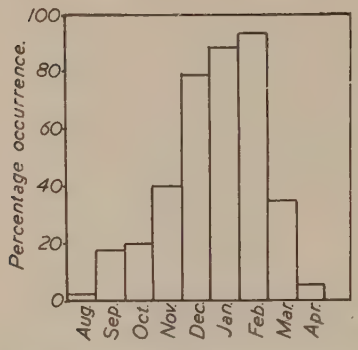

Figure 3. Percentage occurrence of berried females in the sample of prawns between August 1955 and April 1956 in Bantry Bay.

stone boulders of large dimensions, which offer considerable natural cover to the prawns. Local fishermen contend that the prawns are to be found amongst these boulders, when they are ready to shed their eggs. Perhaps such an area as this would afford some measure of initial protection. It is uneconomical to fish again in this area until the late summer.

The mean number of berries counted from a selection of females between 65 and 110 mm was 2195.

In the Crookhaven samples 78% were females and 22% were males, and for Bantry the ratio was 83% to 17% respectively. The Clew Bay samples consisted of 78% females and 22% males. The sample from Creedon Head consisted of 78% females and 22% males. Of the Helvick samples, 61% were females and 39% were males. In the case of the Gowla Beg samples 81% were females and 19% were males.

Summary

L. serratus occurs at very many places around the Irish coast, and is chiefly associated with the weed-covered rocky parts of the shore line well below low-water. It has been noted that where *Zostera* sp. is re-colonizing *Leander* is very commonly found. The mean size of the prawns produced by fishing predominantly with a creel of French design lies between 60 and 80 mm in total length. Creels with a 9·5 mm mesh produce a wide range of sizes and in consequence considerable time is involved if the catch is to be properly sorted. The evidence produced by comparing the catch of an English and a French type of creel suggests strongly that for a number of reasons the latter type of creel is to be preferred.

The Problem of Stunted Growth in Oysters

By

H. A. Cole and **G. D. Waugh**

Fisheries Laboratory, Burnham-on-Crouch, Essex

I. Introduction

The increasing prevalence, in recent years, on British beds, of small thick-shelled oysters which do not increase substantially in size from year to year, is causing anxiety. These oysters are known in the trade as "dumps", "clumps", or "stunters" and their presence on a fishery tends to reduce profitability, since they continue to occupy ground which might carry higher grade oysters. It has been said that one important reason for the decline in the numbers of oysters imported from Brittany in the post-war years, was the high proportion of such stunted individuals amongst the three year-old oysters. Certainly stunted oysters have been found in quantity on certain Cornish beds, on which large consignments of French oysters were relaid, but they also occur commonly on most grounds in Essex where cultivation is primarily of natives.

II. Types of Stunted Oysters

Orton (1925) described a particular type of small rounded and thick-shelled oyster which he encountered on the River Fal beds. He described these as "thick-shelled, pebble-like and apparently slow growing oysters which are conveniently called dumps. Dumpy oysters vary in width from slightly dumpy forms to forms almost like a Brazil nut, but a ring could be devised which would allow good oysters to pass through it and prevent dumps from doing so."

In Figure 1 we have reproduced his drawing. These oysters were to be found at that time on other beds in Devon and south Cornwall, e.g., the River Yealm and the Helford River, but as Fal oysters were relaid regularly on these grounds, it is unlikely that the type occurred naturally anywhere except in the Fal. During the course of a survey made in 1924, Orton (1925) recorded 42% of "dumpy" oysters amongst the stock on the Fal beds. He investigated their breeding capacity (Orton, 1926) and concluded (p. 223) that "during 1925 dumpy oysters spawned in a high proportion on the Fal beds, and although they are not such heavy breeders as normal oysters, they are undoubtedly valuable in forming a stable spawning stock for replenishing the beds in the future."

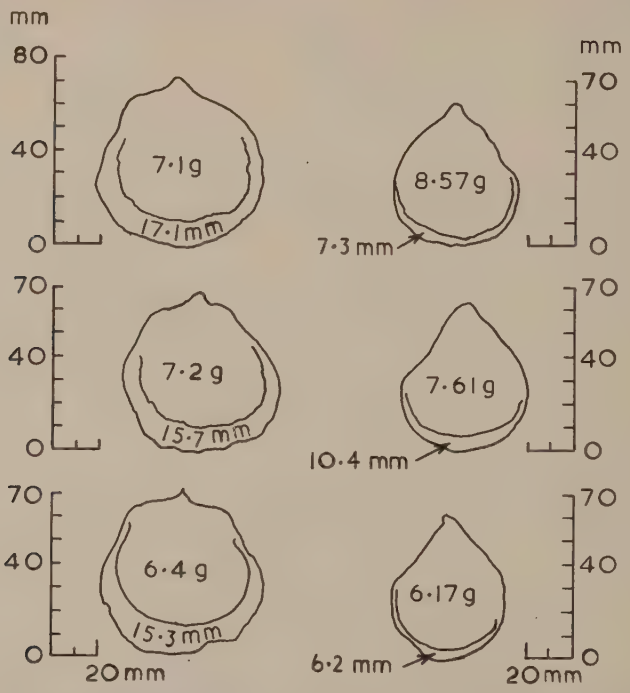

Figure 1. Fal oysters. Diagrams selected from those of Orton (1926) show average size and shape (length by height) of groups of well grown and dumpy oysters. The average weight of oysters in grammes and the approximate average increment of shell-growth in 1925 are also shown.

Oysters of this exaggerated Brazil-nut shape are not now to be found on the Fal beds or anywhere else in Britain. They seem to have died out in the Fal during the war period as there were none to be found during a 1948 survey and their absence has been confirmed by further surveys made (for another purpose) in each subsequent year. It seems therefore that the true dumpy oyster of Orton was a genetic variant which appeared, perhaps by mutation, and failed to survive.

The stunted oyster occurring widely today are not of this type. They are generally very regular in shape, unless attacked also by shell disease (Cole, 1950), thick-shelled, usually deep (i. e., with a fair "heel", to use the trade term), with the right ("flat") valve only slightly arched. Their characteristic is that they rarely exceed 6·5 cm (about 2·5 in.) across the shell, and so do not reach marketable size, except possibly in Grade 4. In consequence, they are returned to the beds, along with other rejects, but when lifted again after 12 months are found not to have altered, noticeably, in size or general appearance. Further relaying, even on different ground, rarely effects any improvement and where such oysters are prevalent it has been necessary to make a special small Grade 5 in which they may be offered at a low price. Clearly the repeated handling and planting of such dwarfed oysters is uneconomic.

III. Possible Causes of Stunted Growth

Temperature and food supply

Our knowledge of the conditions producing steady and rapid shell-growth in oysters is still surprisingly limited. It is known that in enclosed bodies of water such as the Conway breeding tanks (Cole, 1936), where a sustained high level of water temperature may be achieved, very rapid shell-growth occurs in oysters of all ages, even though food may be so scarce as to cause loss of condition. The senior author has noted numerous examples of rapid shell-growth in poor feeding conditions, so unsatisfactory indeed in some cases as to cause heavy mortality, and it is clear that shell-growth and fattening are not closely related processes. For fattening an abundance of available and rich food material is presumably indispensable, but for rapid shell-growth sustained high water temperatures seem to be of major importance. Orton (1928) described spring and autumn shell shoots with little growth during the period between, but shell-growth in young oysters is certainly not of this pattern. Further studies in relation to temperature, degree of exposure, and food supply are desirable.

Bombardment with suspended mineral particles

Stunted growth of the particular type under consideration in this paper is not associated with specially unfavourable conditions of water temperature or food supply. Stunted oysters may occur mixed with others showing normal growth-rate but certain instances have also been noted of particular grounds which produce very poor growth generally and a high proportion of stunters. There is such a ground opposite Creeksea in the River Crouch, Essex, on which survival of oysters is, however, normal. The sole known peculiarity of this particular laying is the strong current which sweeps it on both ebb and flood tides. At this point the river bends and the main channel strikes in near the shore on the south side, almost the whole of the laying being fully exposed. The water of the Crouch carries much silt and sand in suspension and it is thought that it is the presence of this almost constant stream of inert particles which limits shell-growth. The exact process whereby limitation is effected may be supposed to be a general failure of the mantle edge, with its shell-secreting glands, to extend fully in face of a steady bombardment by mineral particles swept along by the current. A strong current without mineral particles in suspension is probably favourable for growth and fattening, since it ensures full oxygenation of the surrounding water and a continuous food supply (Korringa, 1956).

Infestation with *Polydora*

Stunted oysters occurring on grounds known to be capable of producing well grown normally-shaped oysters arise from other causes, some of which are known while others are suspected. Korringa (1951) has shown that, in Holland, elimination of *Polydora* infesting the shells results in marked improvement in rate of shell-growth. In Britain, where in the west and in North Wales, the average degree of infestation with *Polydora* is very much higher than in the Netherlands (300 worms per oyster is not uncommon), the methods used in Holland to clear the shells of the worms have proved ineffective. Very rapid re-infestation of oysters, freed from *Polydora* by dipping in a 0·6 $^0/_{00}$ solution of

phenol, occurs during the spring and early summer; the good effects, if any, of dipping are therefore masked. It is however possible that, in some areas, disinfection of the oysters can be carried out at a time when *Polydora* settlement is least, and whilst water temperatures are still sufficiently high to permit growth of the oysters.

Much observation of the incidence of *Polydora* leaves the writers with a very strong impression that these worms are capable of checking shell-growth very severely, and that they may play a major part in the production of stunted oysters. The problem of determining precisely the damage caused by *Polydora* is not a simple one (Cole and Hancock, 1955) and much basic study of the biology of the worms is needed before substantial further progress can be made.

Conditions on the Helford River beds

Although many stunted oysters are heavily infested with *Polydora*, others are not and occur on grounds on which, in the past, large and well grown oysters were produced. This is particularly true of the Helford River, Cornwall, where in the years preceding the occupation of France in 1940, three year-old oysters from Brittany were laid regularly, yielding large quantities of Grade 1 and Grade 2 oysters after one or two seasons. The importation of Brittany oysters was resumed after the war and continued until 1952, but the results obtained were not satisfactory. Shell-growth was poor and large numbers of stunted oysters appeared on the fishery.

Since that time a careful examination has been made for factors limiting growth in the Helford River. In one series of experiments an attempt was made to correlate rate of growth, condition, and mortality of relaid Brittany, Fal, and Native oysters. The Brittany oysters used were two year-olds imported in March 1952, the Fal oysters were also brought into the river at that time and the Native oysters were dredged from the stock grounds. These oysters and all others used in other experiments were laid out on Penarvon Flats. These are extensive flats of sandy mud, completely bare, uncovered only on equinoctial spring tides.

Mean diameters of the Brittany, Fal, and Native oysters are shown in Table 1. It will be seen that both the Brittany and Native oysters grew reasonably well in the summer of 1952 but that in the summer of 1953 growth was negligible.

Growth-rate of the Fal oysters was also negligible. The Brittany oysters, being smaller and younger, grew most rapidly whilst those from the Fal, which were large when laid, grew little. The Native oysters were a mixed batch of two and three year-old oysters, and their growth was poorer than that of the "Brittanies".

In addition to the two year-old oysters, some three year-olds were also imported from Brittany. Samples of these were laid out on adjacent plots and measured. In this case too, growth in the first season was good, but in the second very poor. Mean sizes of the oysters are shown in Table 2. At the end of the first season the two year-olds were, on average, bigger than the three year-olds when laid, and by the end of the second season a few had reached market size. It seemed, however, that under the poor growing conditions in 1953, only a small proportion of the oysters could add to their shells.

For various reasons no further consignments of Brittany oysters were laid after 1952. Further experiments were therefore conducted using Fal oysters.

Table 1

Showing growth of oysters in 1952 and 1953

Date	Mean diameters of oysters (mm) Brittany	Fal	Native
March 1952	51	66	56
October 1952	61	72	62
March 1953	61	68	63
October 1953	63	67	62

Table 2

Showing growth of Brittany oysters in 1952 and 1953

Date	Mean diameter (mm) 2 year-old	3 year-old
March 1952	49	59
October 1952	64	70
October 1953	65 } 66	70 } 72
November 1953	67 }	74 }

Table 3

Growth of Fal oysters on thickly laid plots

	Mean diameters of oysters (mm) Cultched plot			Uncultched plot		
	E. edge	Centre	W. edge	S. edge	Centre	W. edge
March 1953	66	66	66	66	66	66
October 1953	66	67	69	66	68	65
March 1954	67	68	69	68	67	65
April 1954	67	66	66	67	67	65
November 1954	71	71	70	71	70	71

An attempt was made to discover whether density of laying would affect the rate of growth. Two plots 35 m apart were marked out at the same tide level on Penarvon Flats. Each plot was of 10 m side and one was covered with a substantial layer of old dirty cultch. Fifteen thousand oysters were laid on each plot. At the end of the growing season, oysters were picked at random, using a 0·5 m square, from the edges and middle of each plot. The results are shown in Table 3.

Growth was limited and less than the natural variation of the sample in 1953. In 1954 it was slightly better. However, there was no difference in the sizes of the oysters, i. e., those at the centres of the plots, where they were surrounded by others competing for food, grew as well as those at the edges which were not. The presence of cultch made no difference to the amount of growth. The condition of the oysters as estimated by the technique of Baird (1958) was essentially the same at all places. The poor growing seasons may have masked any effect but it seems that, at least in this particular area, oysters can be laid at the rate of 150 per m^2 (i.e., so that they are touching one another) without harmful effects.

In order to discover whether it was possible to stimulate the growth of dumpy oysters, 4,000 rejects (i.e., below Grade 4) were selected in 1955. These oysters

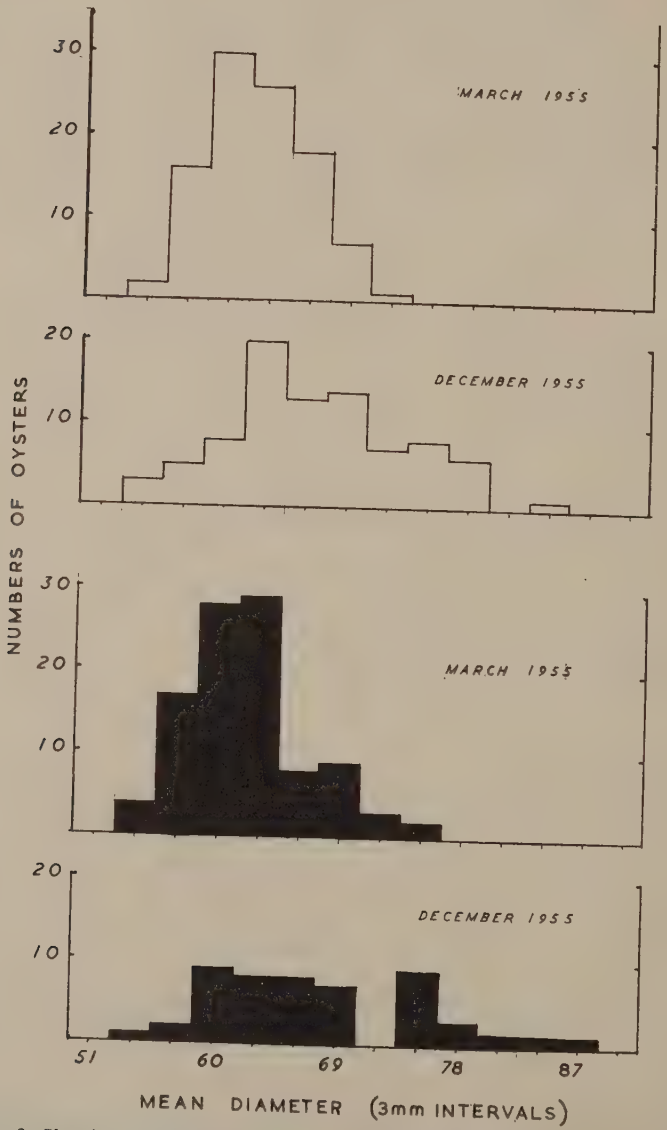

Figure 2. Showing size distribution of reject oysters at the time of selection in March 1955 and after one season's growth. The sizes of the oysters laid on Penarvon Flats are shown in white and those of the oysters transferred to Poole Harbour in black.

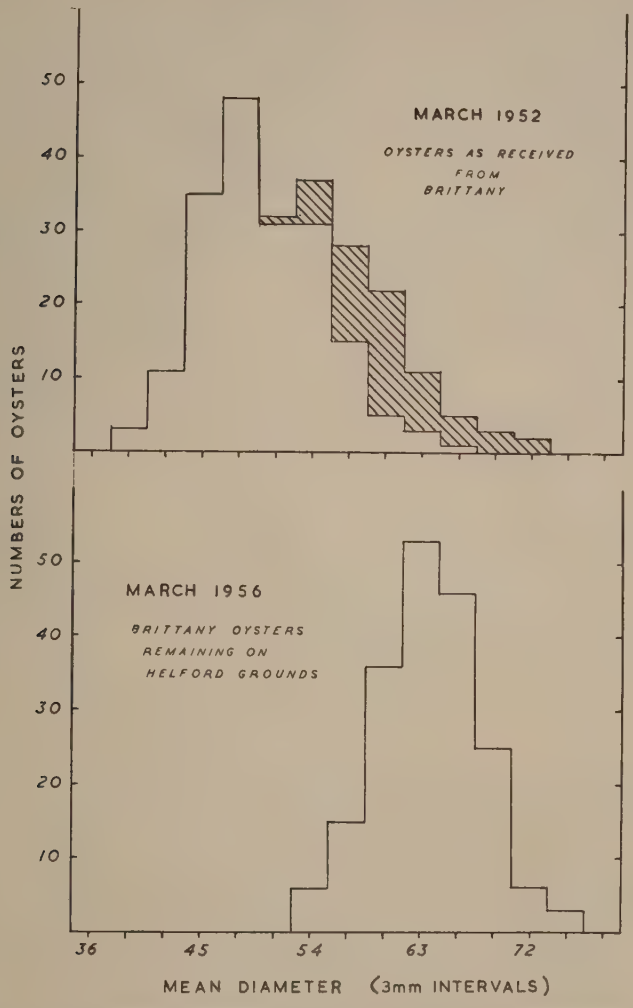

Figure 3. Size distribution of Brittany oysters on the Helford River grounds. The shaded addition to the upper graph is the size distribution of the small proportion of 3 year-old Brittanies that were imported, with the main consignment of 2 year-olds, in 1952.

were a mixture of small Brittany and Native oysters, and they were sorted into a fairly uniform grade. Any which were badly distorted or thought to be affected by shell disease were discarded. The whole sample was soaked in a 1·0 $^{0}/_{00}$ solution of phenol overnight, to kill any *Polydora* in the shells. Two thousand were laid on Penarvon Flats and the other 2,000 sent to Poole Harbour in Dorset. This was formerly well known as a good growing area for oysters.

In point of fact, 1955 was a good growing season on all oyster grounds, and the mean diameter of the oysters in Poole Harbour and on Penarvon Flats increased by approximately the same amount. However, this was because a proportion of the oysters grew well; the rest, the true stunters, did not grow in either locality. This is seen from the size distribution (Figure 2). Although the maximum size had increased appreciably at the end of a year, the minimum size remained the same.

Some Brittany oysters still remained on the Helford River in the spring of 1956. These were the remnants of the consignment laid in 1952. The better growing ones had been sold and the nucleus of "stunters" was left. The size distribution of a random sample of 200 is shown in Figure 3, and compared with the size distribution of the original oysters as received from Brittany. Many of them were still below marketable size, except in Grades 4 or 5. There was, therefore, either something inherent in these oysters which limited their ability to grow, or conditions in the Helford River had changed in such a manner as to be less favourable for oysters. In the light of the Poole Harbour experiments, it appeared that the former was the more likely explanation. Confirmation that conditions in the Helford River had not changed was provided by the rapid growth and development, during 1956 and 1957, of the spat which settled in 1955.

Although the oysters remaining on the grounds had shown only a slight increase in diameter, the thickening and deepening of the shell had resulted in a considerable increase in volume. The mean diameter of the original sample as received from Brittany was 52·4 mm and that of the rejects remaining 63·7 mm; an increase in diameter of 21·6%. On the other hand, the mean volume of the oysters when received was 14·2 ml and that of the remaining stunters was 41·2 ml; the increase in volume, therefore, was of the order of 190%.

Inherent causes

It seems established, therefore, that in the ten years following the second World War, during which French oysters were present on the Helford River beds, they grew less well than in the period up to 1942. There has been no noticeably significant deterioration in physical conditions which would account for this high proportion of stunted oysters. During this same post-war period oysters from Brittany laid in other areas, although not so noticeably unsatisfactory as on the Helford River beds, did not grow as well as expected. There were general complaints of shortage of Grade 1 and Grade 2 oysters, which implied a prevalence of small ones. The difference between conditions on these grounds and those on the Helford River was therefore one of degree. This suggests the existence in the Brittany oysters of some inherent defect preventing them from growing normally. It has seemed as though a certain percentage of the oysters had lost their ability to grow in shell-size notwithstanding planting in reasonably favourable conditions.

The question that naturally follows is whether there has been any change in the methods of cultivation adopted on French beds in the Gulf of Morbihan (the area from which the greater part of the imports to Britain was derived) which could have produced such a change in the growing abilities of the young oysters.

Such a change has, in fact, occurred during the last twenty years. This period has seen a steady reduction in the use of trays (ambulances) for containing the spat during its first few months after removal from the tiles (see LE DANTEC, 1956). Instead the young oysters are being placed, more and more, in specially prepared and fenced plots on the shore at a rather high level (so that they can be protected from crabs and predatory fish and are accessible on smaller tides) so as to eliminate the expense and labour involved in the use of trays. It is agreed that when laid on the shore in this manner they grow less rapidly but this is said to be more than balanced by the reduction in expenditure on labour and materials. That the growth of Portuguese oysters has also been affected adversely by this change is clearly shown by the results of the comparative experiments made by LE DANTEC (1956) at Arcachon.

The suggestion that the check to their growth, now experienced by a large percentage of French oysters at one year-old, may result in some permanent curtailment of their power to put on shell rapidly is, of course, capable of experimental confirmation and it is this task that is being undertaken.

IV. Stunted Oysters on Essex Oyster Beds

In this country stunters are not confined to oysters of French origin; they occur widely but less commonly on grounds confined to the cultivation of Natives. On these grounds it is supposed that spat which settle in unfavourable ecological situations will become stunted unless they are moved during the second summer of their existence, apparently the vital period. The prevalence of such unfavourable situations will be related directly to the state of cultivation of the ground and the abundance of sedentary competitors. These stunted oysters might be expected to occur on semi-derelict grounds heavily infested by *Crepidula*, *Ascidiella*, *Ciona*, and *Elminius* and there is some evidence that this is so, at least in Essex (WAUGH and ANSELL, 1956).

On the best known growing grounds in Britain, those in the Pyefleet (River Colne), native oysters reach a large size and true stunters are virtually unknown. On these grounds only native stock has been cultivated for many years. On the nearby grounds, in the creeks joining the River Blackwater between Tollesbury and West Mersea, to which a variety of oysters, including French, have been introduced in comparatively recent years, the phenomenon of dwarf oysters is, however, well known. Although growth and fattening on these grounds is generally good, the oysters do not, considered over a period of years, reach the exceptionally high standards of those of the Colne and Pyefleet, which are generally conceded to be the finest produced in Britain. The peculiar characters of the Pyefleet, which consistently produces both good shell-growth and fattening, have not yet been analysed.

The suggestion that a low level of nutrition during the first years of life may lead to permanent stunting may seem novel when applied to oysters, but among cattle breeders, the importance of feeding calves well is firmly established. Pedigree breeders in particular give the most careful attention to feeding and management of calves, knowing by experience that a bad start cannot be recovered later, and leaves after effects which will remain with a beast throughout its life. There has also been convincing experimental proof of the effect of low level nutrition on after-growth (BROOKES and VINCETT, 1950).

In oysters the reaction of the tissues responsible for the secretion of shell to environmental conditions, e.g., temperature, must be at a lower level than before a check to growth has been experienced. It is not known whether the check is permanent, but experience suggests that a very drastic change of environment is needed to produce new shell on stunted oysters.

V. The Effect of Market Selection

When selecting oysters for market, it is general practice to cull all the undersized, flat, light, or misshapen oysters and to return them to the beds as "rejects". Usually they are replanted separately and taken up again and re-graded after a further season's growth. As noted earlier, it is a common experience to find that a large proportion of rejected oysters are still unsuitable for market when again lifted, and they are replanted a second or even a third time. Clearly this is uneconomic, and where a trade in small oysters can be developed, it would be most profitable to sell them at first lifting. Such a policy adopted on the Helford since 1954 has resulted in the elimination of the great majority of stunters and a remarkable improvement in the general character of the oysters on the ground.

Where no substantial trade in small oysters is possible, rejects are often planted on a piece of unwanted ground, in the hope that they may breed. They will certainly breed, but it is conceivable that they will produce spat, and ultimately oysters, of inferior quality. There is some reason to suppose that present-day culling practice is leading to the early selection and marketing of a high percentage of the rapid-growing, deep-shelled strains whilst leaving on the grounds those oysters which are inherently slow growing or shallow and flat. Fortunately, since *Ostrea edulis* begins to liberate larvae in substantial numbers at two years old (Cole, 1942), both desirable and undesirable classes act as breeding stock, but the undesirable remain longer on the grounds, and may be supposed to exert a greater influence. Although it may take many years for this practice to affect the quality of the stocks, one cannot but conclude that it would be advisable for oyster planters to follow the example of animal breeders and to eliminate ruthlessly all mature oysters which, for no obvious reasons, are either stunted or lacking in heel. Where there are known environmental influences at work producing either slow growth or a poor shape, then selection can be less severe. Such culled oysters should be sold cheaply, e. g., for cooking, or, if no such outlet is possible, should be stacked on the shore so that their bleached shells may later be used as cultch for the settlement of spat.

VI. Summary

1. During post-war years large numbers of stunted oysters have been found on grounds in Britain, including those on which substantial quantities of Brittany oysters were relaid. These stunted oysters differ from the "dumpy" oysters found by Orton in the River Fal in 1925; the latter are no longer present and it is concluded that they were a genetic variant which has not survived.

2. A review of the recognized causes of stunted growth in oysters, including low temperature, shortage of available food, bombardment with current-borne mineral particles, infestation with *Polydora*, and shell disease, leads to the conclusion that the cause of a substantial proportion of stunting is still unexplained.

3. Experimental investigation of growth conditions on the Helford River, Cornwall, oyster beds has shown that growth differs substantially from year to year but neither relaying at densities up to 150 per m^2, nor the presence of a large quantity of encrusted dead shell, affected growth. Where oysters from Brittany, from the River Fal, and Natives from the Helford River, were laid on the same ground, growth was similar in the three classes.

4. The movement of apparently stunted oysters from the Helford River to Poole Harbour, an area with a high growth potential, resulted in satisfactory growth in a proportion of the sample, but some oysters did not grow at all. Samples of the same batch of oysters retained on the Helford River grounds showed a comparable growth pattern.

5. It is tentatively concluded that a change in cultivation practice on French grounds, whereby oysters at one year-old are laid on the ground rather high up the shore, instead of in trays towards low water of spring tides, as in former years, results in a severe check to growth processes. Of those young oysters affected some apparently lose their capacity to grow normally, even when replanted in very favourable conditions.

Acknowledgements

The work on the Helford River was carried out with the help and co-operation of the management and staff of the Duchy of Cornwall Oyster Farm. To them, and to the directors of Mac Fisheries Ltd., we wish to express our thanks. We are also indebted to the Poole Oyster Group for permission to lay a trial consignment of oysters on their ground in Poole Harbour.

References

Baird, R. H., 1958. "Measurement of condition in mussels and oysters." J. Cons. int. Explor. Mer, **23**: 249–57.

Brookes, A. J., & Vincett, L. S., 1950. "Beef production experiment at Cambridge. Interim Report." J. R. agric. Soc., **111**: 99–118.

Cole, H. A., 1936. "Experiments in the breeding of oysters (*Ostrea edulis*) in tanks, with special reference to the food of the larva and spat." Fish. Invest. Lond., Ser. 2, **15** (4).

Cole, H. A., 1942. "Primary sex-phases in *Ostrea edulis*." Quart. J. micr. Sci., **83**: 317–56.

Cole, H. A., 1950. "Shell disease in re-laid French oysters." Nature, Lond., **166**: 19–20.

Cole, H. A., & Hancock, D. A., 1956. "Progress in oyster research in Britain 1949–1954, with special reference to the control of pests and diseases." Rapp. Cons. Explor. Mer, **140** (3): 24–29.

Korringa, P., 1951. "'*Polydora*' als vijand van de oestercultuur." Viss.-Nieuws, Suppl. 2, **3** (10).

Korringa, P., 1956. "Oyster culture and biological productivity." Rapp. Cons. Explor. Mer, **140** (3): 30–31.

Le Dantec, J., 1956. "Observations sur un essai d'élevage d'huîtres portugaises en caisses ostréophiles." Rev. Trav. Inst. Pêches Marit., **20**: 171–82.

Orton, J. H., 1925. "Summary of a report on a survey of the oyster beds in the Fal Estuary, in November, 1924 with notes on the biology of the oyster." Falmouth, J. H. Lake & Co. Ltd.

Orton, J. H., 1926. "On lunar periodicity in spawning of normally grown Falmouth oysters (*O. edulis*), in 1925, with a comparison of the spawning capacity of normally grown and dumpy oysters." J. mar. biol. Ass. U.K., **14**: 199–225.

Orton, J. H., 1928. "On rhythmic periods in shell-growth in *O. edulis*, with a note on fattening." J. mar. biol. Ass. U.K., **15**: 365–427.

Waugh, G. D., & Ansell, A., 1956. "The effect, on oyster spatfall, of controlling barnacle settlement with DDT." Ann. appl. Biol., **44**: 619–25.

Notes on the Escallop (*Pecten maximus* L.) in Three Closely Associated Bays in the West of Ireland

By

F. A. Gibson

Fisheries Division, Department of Lands, Dublin

The commercial fisheries for escallops in the west of Ireland are situated in three bays on the north coast of Galway Bay, (Greatmans, Kilkieran, and Gortaboy Bays). These three bays are in close proximity to each other, and in fact Greatmans and Kilkieran Bays are connected at their heads by a navigable channel. GIBSON (1956) noted considerable differences in the stocks of escallops from these areas and therefore an opportunity was taken from November 1956 to April 1957, to study this question further during the course of sampling from these areas in connexion with the bye-laws governing escallop fishing. At present a close season from 16. June to 31. December prohibits the landing and sale of escallops from this area. Furthermore, this bye-law fixes $4\frac{1}{4}$ inches (10·8 cm) as the legal minimum size. The primary object of the study therefore was to sample the catch and determine the overall condition of the meats during the early part of the annual fishery, and to relate the existing size limit with the age at which the escallops appear to enter the commercial fishery. Incidental to these matters, it was possible to relate the penultimate size of the escallops caught to the gap between the teeth of the traditional type of escallop dredge operated in this area. Relevant material from GIBSON (1956) has been utilized also for comparison with the County Galway material at present being studied. Limited observations of the depths and the nature of the bottoms in these three bays were also made.

Gortaboy Bay is very exposed and escallop fishing is often interrupted by adverse weather conditions. The bottom here has large areas of sand and coral. Escallops produced from it have clean, light coloured shells, and have a comparatively slow growth-rate. The mean depth of this bay is about 6 fathoms (11 metres). Because of shelter afforded by the islands, escallop fishing can continue over a longer period in Kilkieran Bay than in Gortaboy Bay. The bottom is composed very largely of hard packed mud, with an extensive area of weed, shell, and stones. Escallop shells from this area are normally of a dark colour and silt is engrained into the shell. The mean depth is approximately 7 fathoms (12·8 metres). Greatmans Bay is a narrow inlet, sheltered from the

Table 1

Showing the percentage occurrence of the five stages of gonad development in samples of escallops from the three areas. Note, no samples were received for March 1957

Month	Spents V	Recovering spents I	Filling II	Full III	Spawning IV
			Greatmans Bay		
November, 1956....	4·5	31·8	36·2	25·1	2·3
December, 1956....	3·3	16·4	53·9	26·3	–
January, 1957....	1·7	11·7	33·3	53·3	–
February, 1957....	–	16·0	6·0	78·0	–
April, 1957....	–	–	–	100·0	–
			Gortaboy Bay		
November, 1956....	22·6	26·7	45·2	1·1	4·3
December, 1956....	8·1	30·6	31·4	30·6	–
January, 1957....	6·7	25·0	20·0	48·3	–
February, 1957....	–	4·2	21·2	74·6	–
April, 1957....	–	5·5	–	94·5	–
			Kilkieran Bay		
November, 1956....	21·6	47·4	22·4	6·5	2·1
December, 1956....	20·6	33·8	23·5	20·5	1·5
January, 1957....	9·8	29·5	50·9	9·8	–
February, 1957....	–	14·6	66·7	18·7	–
April, 1957....	–	1·7	11·5	86·8	–

prevailing winds. The bottom is very largely composed of hard mud, weed, and areas of coral. The mean depth is about $3\frac{1}{2}$ fathoms (6·4 metres). Escallops from Greatmans Bay are reputed to come into condition earlier each year than those from either Gortaboy or Kilkieran Bays.

In the months of November and December 1956, samples of the catch were examined by the writer during fishing operations. Samples were received in the Fisheries Labaratory for the months of January, February, and April 1957. In all cases the samples were taken by a traditional type of commercial escallop dredge as described by GIBSON (1956). The entire catch from each dredge haul was examined in November and December but the January to April samples were selected by the fishermen from their catches and therefore they have only been used for condition of the gonads and growth-rates. Each escallop was measured from the umbo to the ventral margin and from the anterior to the posterior end. The age and growth-rate was determined as described by GIBSON (1956), and the gonads were equated to the five stages of condition as described by the same author. The majority of post-larval escallops appear annually from April to October, and the mean greatest settlement of them takes place in early summer and early autumn. At the end of the year, say December, such juveniles are on average between 4 and 6 months old. Therefore, at the end of the second year, they are between 16 and 18 months old. A 2-group escallop, therefore, may be up to 30 months old, and have completed 3 growing periods.

The condition of the gonads for the three areas from November 1956 to April 1957 is indicated in Table 1. In Greatmans Bay in November and December there were 36·3% and 19·7% of spents and recovering spents (stages V and I), respectively, and their percentage occurrence fell to 13·4% in January.

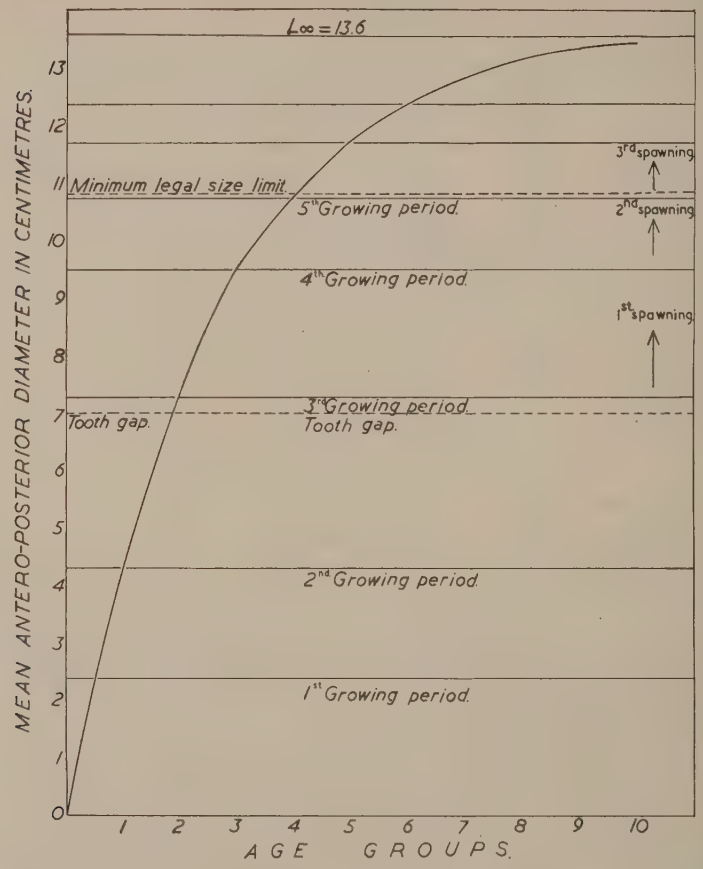

Figure 1. Greatest diameter growth curve constructed from Galway Bay material for November, December 1956, and January, February, April 1957. The relationship of growth to (a) the tooth gap spacing and (b) the minimum legal size limit is shown. The first five growing periods are shown in relationship to the spawning times.

There were 16·0% of recovering spents in February but no spents in either February or April. By February, 78·0% of the samples were at stage III, i.e., full and preparing for spawning, and the April samples were 100% in this condition.

In November and December in Gortaboy and Kilkieran Bays, 49·3% and 69·0%, respectively, were spents and 38·7% and 54·4%, respectively, recovering spents. In January, the percentage occurrence of these stages was 31·7% and 39·3% for the two bays, respectively. Again there were no spents in February or April. By February, 48·3% of the Gortaboy samples were in stage III of development and in Kilkieran Bay only 18·7% were in this condition at that time. In April, 94·5% of the Gortaboy Bay and 86·8% of the Kilkieran Bay samples

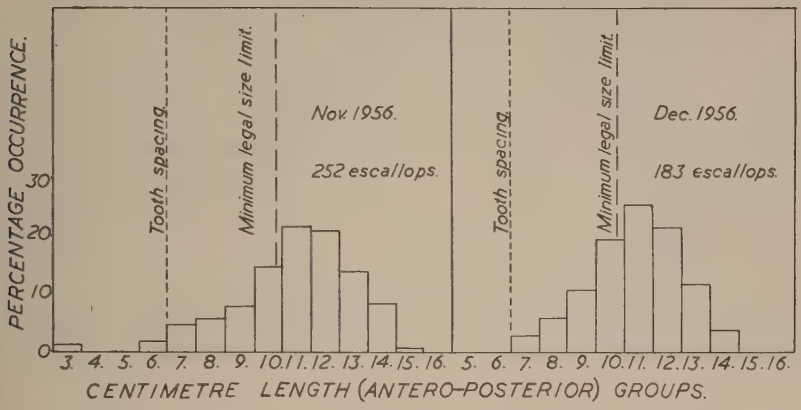

Figure 2. Size distribution (greatest diameter) of November and December samples, in relationship to tooth gap spacing and the minimum legal size limit.

had reached stage III. The indication from these observations is that a larger number of Greatmans Bay escallops reached prime condition earlier than in either the Gortaboy or Kilkieran areas. It is possible that conditions for recovery may be more suitable in Greatmans Bay than in the other two bays. It is probable that in Greatmans Bay, where the average depth is $3\frac{1}{2}$ fathoms, that there is a higher mean water temperature during the period of the year when escallops are making their annual increment of growth, that is to say from approximately April until October. During the same period in the case of Kilkieran and Gortaboy Bay where the mean depth is considerably greater, the water temperatures are probably lower and therefore the growth-rate may be slower, as pointed out by Mason (1957). Furthermore Greatmans Bay being shallower than either of the other two, and less subject to tidal disturbance, may contain a more abundant available food supply, and longer periods during which the escallops can actively feed. It is probable therefore that the rate of growth and the condition of escallops is determined by a combination of factors including high mean temperatures and maximum feeding periods.

The relationship of the present size limit to the growth in length of escallops is shown in Figure 1. The mean greatest diameter measurement (anterior-posterior) of the 2-group escallops at the beginning of their third growing period is 73 mm; that for the 3-group, 95 mm; for the 4-group, 108 mm; and for the 5-group, 118 mm. The first spawning probably takes place in the summer or autumn prior to the escallop reaching a size of 95 mm, that is to say at the end of their fourth growing period (growing periods being taken to be from March or April to October or November (Gibson, 1956)). The second spawning takes place in the summer or autumn prior to their reaching a size of 108 mm. The present size limit is of approximately the right order but it is only the presence of a close season (16. June to 31. December) which allows the second group of spawning escallops to contribute to recruitment in the fishery. On the other hand, if the size limit were raised to $4\frac{1}{2}$ inches (114 mm) this group would almost

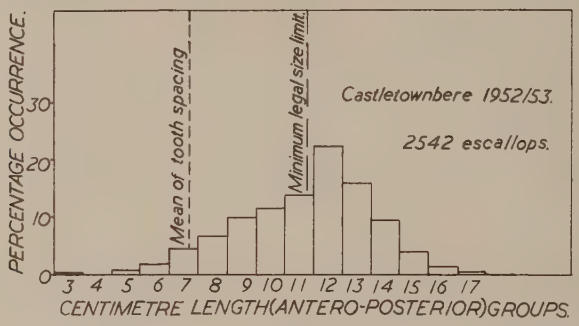

Figure 3. Size distribution (greatest diameter) of Castletownbere material 1952 and 1953, in relationship to tooth gap spacing and the minimum legal size limit.

certainly spawn before entering the commercial fishery. The need to allow the 2- and 3-groups to spawn has been shown by BAIRD and GIBSON (1956, Figure 1). In the hand-picked sample taken at Castletownbere in 1953 these two groups formed up to 34% of the total (the 0- and 1-groups forming 62·0%). If therefore the 2- and 3-groups can be protected, there appears to be no reason why escallops of the 4-group and older could not be fished rigorously and yet not interfere with the viability of the fishery. However, fishermen are often unwilling to observe a legal size limit, and another method of conserving the stocks might be adopted. In Figure 2 the relationship of the escallop's length frequencies to the dredge tooth spacing is shown in November and December 1956, for the three inlets of Galway Bay. The tooth spacing selection operates, as the present evidence appears to suggest, in such a way as to eliminate to a considerable extent escallops which are smaller than the gap between the teeth. In Figure 3 the combined mean occurrence of age-groups for the Castletownbere material, based on GIBSON (1956) provides additional evidence which tends to support tooth selection. During this work the mean dredge tooth spacing was 78 mm. This tooth spacing is in fact similar to that used in the west of Ireland dredges when the material for November 1956 to April 1957 was being collected. It has been found that there is considerable variation in the tooth gap spacing used by particular fishermen even within each fishing area. The first appreciable appearance of a strongly represented size group in the Castletownbere fishery occurs at a size of 70 mm. A marked rise occurs in the 90 mm size group (Figure 3). A dredge sample taken in conjunction with diving at Castletownbere in September 1953 (BAIRD and GIBSON, 1956), shows that on this occasion an 80 mm tooth spacing appears to be related to the size at which quantities of escallops enter the catch. In all cases these commercial samples are in sharp contrast to the randomly taken dive samples analysed by BAIRD and GIBSON (1956). Escallops are probably in best marketable condition during early spring and from thence until early autumn, and therefore would be most suitable for market at that time. A close season which limits fishing for them, when they are in this condition, is not achieving the best result from the fishery. The available evidence suggests that providing all escallops of $4\frac{1}{2}$ inches (114 mm) and under are not taken, this portion of the population will be sufficient to ensure the future of the fishery. The present information would also seem to

indicate that there is a relationship between the size of the escallops landed and the gap between the teeth. As for mesh selection in fish, the tooth gap would not exclude all escallops under the minimum size. It might have the effect of concentrating the effort upon escallops of the desired size, so that if a size limit is at the same time imposed, the greater proportion of the undersized escallops appearing in the catch would be returned to the beds. In this way prescribed fishing seasons could be eliminated, thus allowing the fishery to develop along lines not dependent upon the condition of the gonads. Futhermore there is considerable time variation annually at which the gonads will be found in any particular stage of development — so that a fishing season tends to be too generalized to cope with this situation. At the same time the adoption of a compulsory tooth spacing of a size yet to be specified might regulate the exploitation of the stock and under normal conditions allow maximum opportunities for recruitment. If the bye-law limiting the size to $4\frac{1}{2}''$ (114 mm) was generally applied the same ideal condition would be attained, but it is felt that by itself, a size limit is insufficient to achieve this aim.

Summary

From consideration of work done in the West and South of Ireland, the author considers that the fixing of a minimum spacing between the teeth of dredges used for escallop (*P. maximus*) coupled with enforcement of a minimum size limit (11·8 cm is suggested) is likely to have a more important conservation effect than close seasons and size limits.

References

Baird, R. H., & Gibson, F. A., 1956. "Underwater observations on escallop (*Pecten maximus* L.) beds". J. mar. biol. Ass. U.K., **35**: 555–62.

Gibson, F. A., 1956. "Escallops (*Pecten maximus* L.) in Irish waters". Sci. Proc. Roy. Dub. Soc. (N.S.), **27**: 253–70.

Mason, J., 1957. "The age and growth of the scallop *Pecten maximus* (L.), in Manx waters". J. mar. biol. Ass. U.K., **36**: 473–92.

Notice

A Central Agency for ^{14}C Determination (Measurements of Primary Production in the Sea) at Charlottenlund Slot, Denmark

During recent years the study of the primary production in the sea has been one of the main concerns of marine science. The present great interest in productivity is due *inter alia* to the use of the radioactive tracer ^{14}C as a tool for measuring primary production in the sea regardless of the size of the production. STEEMANN NIELSEN first employed the ^{14}C method for measuring the production of organic matter in the sea on the deep-sea expedition of the "Galathea", 1950–52. The technique has now been used by many investigators all over the world and it has been routinely included both in oceanographic data-gathering voyages and on lightships, where the field work is made by the crew.

The most recent description of the different modifications of the ^{14}C method is found in the articles B.2 and B.3 in "Contributions to Plankton Symposium 1957, Measurements of Primary Production in the Sea". (Rapp. Cons. Explor. Mer, **144**, 1958.)

An important factor in the usefulness of the ^{14}C technique for measuring primary production is that the field work does not presuppose any expert knowledge. On the other hand, the manufacturing of the ampoules containing the solution of $NaH^{14}CO_3$ to be used for the experiments requires a well equipped laboratory and a scientist familiar with radioactive tracer work. The same is true concerning the measurements of the radioactivity of the filters containing the samples.

Whereas large oceanographic institutions ordinarily will have such an expert at their disposal, this will not be true for many other marine laboratories. In several instances therefore various institutions have cooperated. The ampoules to be used have been manufactured at one place and sent to another where they have been used for productivity work. The dried filters with the radioactive plankton have in turn been sent back to the first place for measurement. As the half life of ^{14}C is more than 5000 years, the filters, if properly stored, remain unaltered for a very long time.

During the symposium on "Measurements of Primary Production in the Sea" held at Bergen 27.–29. September 1957 by ICES, an *ad hoc* working committee was appointed to deal with the methods for the measurement of primary production. The members were: John H. RYTHER (Chairman), Grim BERGE, Maxwell S. DOTY, G. E. FOGG, and E. STEEMANN NIELSEN.

The committee presented recommendations which were adopted unanimously by the about 80 participants of the symposium. One of the paragraphs read: "It is suggested that a central agency be established, for example at Charlottenlund under the direction of Prof. E. STEEMANN NIELSEN, which would provide

standardized ampoules of ^{14}C, counting of ^{14}C samples, and calculation of carbon assimilation rates."

In January 1958, UNESCO provided funds for establishing the agency. The "Danish Institute for Fisheries and Marine Research" provided a room at its residence at Charlottenlund Slot, Denmark.

The agency is organized on a non-profit basis. Professor E. Steemann Nielsen, who is adviser on plankton research to the "Danish Institute for Fisheries and Marine Research", will be honorary supervisor. The daily work will be directed by Mr. Vagn Hansen of the same institute. The facilities of the agency, which was officially opened during the meeting in October 1958 of ICES, are available to all scientific institutions in the world. The consignments will be made in accordance with rules set up by the Danish Ministry of Health.

Standardized ampoules of ^{14}C activity 0·004 mc. may be obtained from the agency at the following prices: —

100 ampoules or more	D. kr. 2.75	each
50–99 ampoules	– – 3.00	–
less than 50 ampoules	– – 3.25	–

If the purchaser wishes to have the filters containing the samples from experiments counted by the agency the total price (including ampoules and numbered membrane filters) will be: —

100 ampoules or more	D. kr. 5.00	each
50–99 ampoules	– – 5.25	–
less than 50 ampoules	– – 5.50	–

The prices include packing but exclude transport. Special boxes for the return of the filters when the counting is to be done by the Central Agency will be provided.

The salinity of the sea water used for the experiments must be stated by a customer. It will be sufficient for water from the open ocean to designate "ocean water". The photosynthetic rate will be computed by the agency. When using either brackish water or fresh water it will be necessary for the customer to determine the total concentration of carbon dioxide in the water.

The water samples to be used for the experiments should be taken with a glass, plastic, or other type non-metallic, non toxic sampler.

Directions for use of ^{14}C tracer will be enclosed in each consignment.

Special holders to be used when drying filters may be obtained at a price of D. kr. 8.00 each.

A filtration apparatus operating by pressure obtained by a bicycle pump may be provided from the Central Agency at a price of D. kr. 300.00.

A suitable water sampler may be provided by Laboratoire Hydrographique, Copenhague, at a price of 830.00 D. kr.

Field kits for sample collecting, filtration apparatus, filters, etc. may also be provided, on request and at cost price, by Prof. Maxwell S. Doty, Botany Department, University of Hawaii and by Dr. John H. Ryther, Woods Hole Oceanographic Institution, Woods Hole, Mass., U.S.A.

E. Steemann Nielsen

Letter to the Editor

Water Temperature and Cod Growth-Rate

Clyde C. TAYLOR's (1958) interesting paper in the *Journal du Conseil* on the relation of cod growth-rate to water temperature is unfortunately marred by a misuse of terms which has led its author into a logical labyrinth. TAYLOR chooses to express the rate at which cod approach their asymptotic size by a transformation of the parameter K of the von Bertalanffy formula for growth in length (his equation 6). Then, having called this the "life-span", concludes that changes in K, which might arise from temperature differences, can, because they imply changes in "life-span", affect the age composition as well as the length composition of the population. This is absurd, and to suggest that "if temperature-dependent changes should occur they might be mistakenly interpreted as effects of fishing" is to put a very low value on the common sense of fisheries biologists. I do not know of any recent case where a reduction of the average size of fish in the catches has been cited as scientific evidence of an effect of fishing unless accompanied by some evidence that the observed change is not the result of an altered growth-rate, or at least that the size change is of the order of magnitude expected to result from a measured change in fishing intensity *if* there were no change in growth-rate.

Some fish live long enough to approach their asymptotic size quite closely; others do not. The life-span is determined by the mortality, not the rate of growth, and a change in K unaccompanied by a change in mortality would simply result in fish dying at a size which is on the average a different fraction of the final size than formerly. They would die at the same average age as before unless there were a real dependence of mortality rate on growth-rate; this is possible and needs investigation, but TAYLOR has not provided any evidence of this in cod and therefore his contention that temperature changes could account for some of the observed changes in age composition of cod stocks cannot be upheld.

It is necessary to draw attention to this question because the temperature relation so clearly demonstrated in TAYLOR's paper might be important in future population studies. Before such a correlation can be regarded as evidence of a causal relation further analysis is required, since we are by now familiar with the misleading properties of spurious correlations. Some hint is given by consideration of von BERTALANFFY's differential equation: —

$$\frac{dw}{dt} = Hw^{2/3} - kw \quad \text{where } k = 3K \text{ and } L_\infty \propto HK.$$

It would be expected that the rate of catabolism expressed by K would, like other physiological processes, increase logarithmically with temperature, at a rate equivalent to the usual values of Q_{10}, at least until harmful temperatures are approached. The value of the anabolic coefficient H, on the other hand, is determined partly by physiological processes and partly by ecological ones and would be expected to increase with temperature, but not as fast as

K. L_∞, which is proportional to the ratio H/K, would therefore decrease, but rather slowly with increasing temperature. This is what the second and fourth columns in TAYLOR's Table 1 show directly.

If similar relations were to be demonstrated for some other species and stocks we should have a method to help in interpreting data for species in which it is difficult or impossible at present to determine age and hence the absolute growth-rate.

At a recent seminar on the biology of the chub mackerel, *Rastrelliger* spp., which are very important economically in the Indo-Pacific region the growth data available for other scombroid fishes were reviewed (HOLT, 1958). The values of K for *Scomber scombrus*, *S. colias*, *Pneumatophorus diego*, and *P. japonicus* were all within the range 0·25–0·54. L_∞ varied from species to species and from place to place, but H was always within the range 0·9–1·2. In general K was higher and L_∞ lower for stocks and species in warmer waters. In stocks for which data were available it was noticed that the median length of attainment of maturity was just over two-thirds of L_∞, in accordance with observations on other fish groups. A length of 0·67 L_∞ corresponds with a weight equal to 0·29 W_∞, at which size the rate of increase in weight is at a maximum.

The length at maturity of *Rastrelliger kanagurta* in the Indian fisheries is about 22·5 cm, which would imply that L_∞ is about 31–33 cm. For this stock the lengths at ages one and two years are known from the movement of modes in length-frequency distributions. Given L_∞ and the size at two ages it is possible to determine K, and a value 0·65 was obtained by this method ($H = 1{\cdot}4$).

Analysis of frequency distributions of *R. neglectus* landed at Bangkok suggested the existence of four groups with modal lengths of 15·6, 17·5, 18·8, and 19·8 cm respectively. These give values of $L_\infty = 22{\cdot}5$ cm and $TK = 0{\cdot}35$, where T is the age-interval between successive modes. Comparison with the other species suggested that T must be about half a year. This agreed with observations by Thai biologists that the seasonal curve of gonad weight/body weight is bimodal, indicating two spawning periods six months apart. The length at maturity is about 17 cm, so $H = 1{\cdot}2$ and $K = 0{\cdot}7$.

The parameter K (and also H) is therefore higher in these tropical scombroids than in the others investigated. Further studies should show whether the difference is commensurate with the differences in habitat temperature.

The possible use of such comparative analyses is obvious when it is remembered that so far the age of *Rastrelliger* and other tropical fishes cannot be determined from rings on hard structures. Furthermore, it is always difficult to interpret the length compositions of catches of migratory pelagic fish, and especially those which can spawn at two or more seasons each year or even throughout the year. If tentative age analyses can be checked by comparison with expected K values, another weapon will have been added to the fisheries biologists' armoury.

Assessments of the effects on catches of changes in fishing depend primarily on knowledge of the ratios of the instantaneous mortality coefficients M and F to the parameter K. Now it does seem that fishes which grow rapidly towards their asymptotic size tend to have shorter lives than the more leisurely ones; this would mean that the inter-specific variability of the ratio M/K is less than the variability of either M or K. There are data from which K can be estimated for several hundred species, but for very few do we know M, though in those few cases the ratio M/K is about unity for a range of mortality values. A

thorough review of published data might well narrow the limits of probable values of this ratio, and thus, given K, the probable limits of the natural mortality in any particular stock for which this elusive factor cannot yet be measured. We are now on less sure ground, but nevertheless I hope enough has been said to show that it is not too early to encourage the comparative studies of fish stock dynamics which were discussed in 1957 at the Joint Scientific Meeting of ICES, ICNAF, and FAO at Lisbon.

S. J. Holt,
Fisheries Division, FAO, Rome.

References

Holt, S. J., 1958. "Report of the International Training Centre on the Methodology and Techniques of Research on Mackerel (*Rastrelliger*)." Mimeo, Bangkok, 5 Dec., 1958.
Taylor, C. C., 1958. "Cod growth and temperature". J. Cons. int. Explor. Mer, **23**: 366–70.

Review

Lionel A. Walford. "Living Resources of the Sea. Opportunities for research and expansion". The Ronald Press Co., XV — 321 pp. New York, 1958.

As research in a scientific field develops and knowledge accumulates, so the subject matter becomes more diverse, complex, and specialized. In consequence, the research worker finds it increasingly difficult to keep abreast of this knowledge and maintain a clear up-to-date picture of progress in the field as a whole. A major contribution to the alleviation of this difficulty is the production of up-to-date text-books or reviews of accumulated knowledge in the field. However, these are not always sufficient because, while they supply what *is* known, they seldom present an appraisal of it in the light of the principal objectives so that what is *not* known can be seen in perspective. Only by such an appraisal can maximum efficiency in research planning and in the utilization of research facilities be achieved. The great merit of this book is that it provides such an appraisal of current knowledge and investigation of the "Living Resources of the Sea" from the standpoint of man's vital interest and concern in them as sources of food.

The pressing human problem which governs this interest and concern is stated with sobering clarity in Chapter 1. The author says: "Human populations are growing tremendously; in some regions they have far outstripped their food supply. Starvation — food deficiency of one kind or another — is widespread throughout the world. ... It is a problem which cannot be solved simply by shipping excess supplies from the richer to the poorer regions. ... In what ways then can needy people magnify their food supplies by their own efforts? ... Yet even with the benefits of agricultural science, production is still not enough to satisfy world needs. Some other sources of very large quantities of

food especially of animal protein food must be found, where? Many food economists have pointed to the sea as the most likely place. This idea seems logical". The succeeding 16 chapters provide an informative and critical appraisal of what is known about the sea's living resources and the ways in which they are being investigated throughout the world in the light of these urgent food needs, special attention being paid to gaps in present knowledge, the stumbling blocks to progress, and the deficiencies of current research efforts and policies.

The first, and perhaps most important and difficult problem underlying the fulfilment of these needs is dealt with all too briefly in Chapter 2, with the aid of twelve highly instructive world maps. It is the simple but inescapable problem of the geography of world population and its food demands and supply. The world's population is not evenly distributed, nor are its cultures, traditions, wealth, living standards, and food demands. Similarly, the exploitation and investigation of the sea's resources vary widely over the world. In general the food needs are greatest in areas where current knowledge and investigation of the sea's resources are least and where wealth, technological standards, and cultures are least suited to rapid, mechanized fishery developments. In consequence, the "urgency" of the main problem is inversely related to the extent of scientific knowledge of the sea's resources and the degree of exploitation of them. The first requirement is therefore more investigation of the sea's resources in those regions of the world where the food needs are greatest.

The author itemizes four possible ways by which food production from the sea might be increased. These are:—

(1) by surveying unexplored areas in search of new food resources;
(2) by harvesting and processing animals and plants which are not now used;
(3) by controlling rates of exploitation so as to give maximum production (conservation);
(4) by farming sea plants and animals in inshore enclosures.

Chapters 3–12 deal in a most informative and provocative way with the factors governing the application of these methods in different parts of the world, what is known about their operation and how and where research might be improved, increased, or redirected to achieve a better understanding of them. The wide scope of the subject matter covered is revealed by the chapter headings. These are as follows:— conservation, the identity of species, environment, the uses of ecological principles, behaviour, harvesting plankton, farming the brackish waters, the role of disease, poison, fishing vessels and gear. Although each of these chapters is largely self-contained, collectively they provide an appraisal of this diverse and complex subject, in which the author draws freely from his large fund of experience and knowledge of fishery problems and research in all parts of the world.

As well as illustrating the impressive growth in some parts of the world during the present century of knowledge of the resources of the sea and their potentialities as sources of food, the author provides ample evidence of wide gaps in knowledge, which in large measure can be attributed to deficiencies in current programmes of research. These concern chiefly the elucidation of the biological and ecological mechanisms which govern the distribution, abundance, and behaviour of the stocks or communities of marine organisms. Even in the regions of long-standing research, knowledge of these mechanisms is often scanty or absent. The need for more attention to this aspect of research

is stressed with emphasis, and the author shows how biological and ecological principles, established in one region, may assist not only in improving the utilization of its resources but also in speeding up or economizing research in regions where it is most needed and the available scientific resources are small. In some regions, where present facilities are adequate, this can be achieved by a reorientation of research effort, organization and policy, but in others, (often where it is most needed) more, better equipped, adequately staffed, and more heavily financed research establishments are required.

In the last five chapters, in two of which world distribution maps are included, the author provides a background account of five of the major groups of exploited marine living resources as they are known today. These are, the invertebrate animals, fishes, reptiles, marine mammals, and seaweeds. The distribution, centres of abundance, and current utilization of each group is described. These serve as a useful summary picture for the more important appraisal of the earlier chapters.

This book is not a text-book; the author did not intend it to be. In many of its chapters it is provocative and controversial, and many readers will not agree with some of the diagnoses of present deficiencies in research or of the proposed remedies. However, few can fail to be stimulated by the author's analysis of the problems which provoke them. By the nature of its contents, it is addressed to those responsible for administrating, financing, and directing research as well as the research worker. It is in fact a book which should be read with profit by all concerned with the science of the sea.

B. B. Parrish

Current Bibliography

Prepared by A. R. MARGETTS

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

1) General Oceanography and Fisheries

1) a Expeditions

ANON. "Data record of oceanographic observations and exploratory fishing. No. 1". Fac. Fish. Hokkaido Univ., Hakodate, 1957.

ANON. "International Geophysical Year. Working Group on Oceanography of CSAGI. Minutes of meetings held in Barcelona, September, 1956". IUGG Chronicle, **1**: 29–36. Paris, 1957.

ANON. "The Soviet Antarctic Expedition of the Academy of Sciences of the USSR. The studies of the marine expedition". IUGG Chronicle, **5**: 206. Paris, 1957.

ANON. "'Helland Hansen' the new research vessel of Geophysical Institute, Bergen". Norwegian Fish. News, **4** (3): 22–23. Bergen, 1957.

ANON. "Canadian hydrographic survey vessel 'Baffin'". Polar Record, **8** (57): 560. Cambridge, 1957.

AUSTIN, T. S. "Summary, oceanographic and fishery data, Marquesas Islands area, August–September, 1956 (EQUAPAC)". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **217**. Washington, 1957.

MOSBY, H. "Narrative of the expedition". Sci. Res. "Brategg" Exped. 1947–48, **1**. Bergen, 1956.

POSTNOV, V. A. "The 'Mikhail Lomonsov', a new research vessel". Priroda, 1957 (10): 108. Moscow, 1957.

1) c Institutes

ANON. "Twenty-fifth annual report of the Department of Fisheries. 1954–1955". Ottawa, 1956.

ANON. "Annual report of the Marine Biological Laboratory". Biol. Bull., **113** (1): 1–48. Lancaster, Pa., 1957.

ANON. "Tenth annual report of the director, 1st April 1955–31st December 1956". Fish. Industr. Res. Inst., Cape Town, 1956.

Anon. "The Woods Hole Oceanographic Institution. Report for the year 1956". Collect. Repr. Woods Hole Oceanogr. Inst. 1957, Woods Hole, 1957.

Anon. "Årsberetning fra Danmarks Fiskeri- og Havundersøgelser for 1955". Copenhagen, 1957.

Anon. "Jahresbericht Nr. 11 für das Jahr 1956". Deutsches Hydrogr. Inst., Hamburg, 1957.

Anon. "Twenty-fifth annual report for the year ended 31 March, 1957". Freshwater Biol. Assoc., Ambleside, 1957.

Anon. "Report on the Northern Ireland sea and inland fisheries 1954–56". HMSO, Belfast, 1957.

Anon. "Annual proceedings for the year 1956–57". Internat. Comm. N.W. Atlantic Fish., Ann. Proc., **5**. Halifax, N.S., 1957.

Anon. "Annual report for the year 1956". Internat. North Pacific Fish. Commiss., Vancouver, 1957.

Anon. "Quarterly report on fisheries research, June, 1957". Rep. Univ. Miami Mar. Lab., **57–19**. Coral Gables, Fla., 1957.

Anon. "Jahresbericht über die deutsche Fischerei 1956". Verlag Gebr. Mann, Berlin, 1957.

Barriéty, L. "Rapport de fonctionnement du Centre en 1956". Bull. Centre Etud. et Rech. Sci. Biarritz, **1** (3): 445–52. Biarritz, 1957.

Böhnecke, G. "Die ozeanographischen Arbeiten im Internationalen Geophysikalischen Jahr (IGJ). Übersicht über die Planungen und Ziele". Deutsche Hydrogr. Zeitschr., **10** (2): 33–38. Hamburg, 1957.

Deacon, G. E. R. "Marine research – the work of the National Institute of Oceanography". Proc. Roy. Soc. Edinburgh, **64** (4): 350–68. Edinburgh, 1957.

Dietrich, G. "Ozeanographische Probleme der deutschen Forschungsfahrten im Internationalen Geophysikalischen Jahr 1957/58". Deutsche Hydrogr. Zeitschr., **10** (2): 39–61. Hamburg, 1957.

Graham, H. "Annual report of the Woods Hole Laboratory". US Dept. Inter., Fish & Wildl. Serv., Woods Hole, 1957.

Maldura, C. "Relazione sull'attività del Laboratorio Centrale di Idrobiologia durante l'anno 1956". Boll. Pesca, Piscicolt. e Idrobiol., **11** (2): 161–64. Roma, 1956.

Tåning, Å. V., & Hansen, P. M. "Fiskeriundersøgelser i 1956". Skr. Danmarks Fisk.- og Havunders., **17**. København, 1957.

Wundsch, H. H. "Die Organisation der fischereiwissenschaftlichen Forschung und Arbeit in der Deutschen Demokratischen Republik". Zeitschr. Fisch. Hilfswiss., **5** (7/8): 487–504. Berlin, 1957.

1) d General Phenomena

Bogaevskii, V. T. "'Figure' phosphorescence in the Hunters Sea". Priroda, 1956 (10): 112–13. Moscow, 1956.

Burling, R. L. "Some unusual reflections of sound in the ocean". Geophysics, **21** (3): 765. Tulsa, Okl., 1956.

Fish, M. P. "Animal sounds in the sea". Sci. American, **194** (4): 93–95, 97–98, 100, & 102. New York, 1956.

Maeda, T., Ueno, M., & Saito, I. "Studies on deep scattering layer. On the DSL off the west coast of Kamchatka Peninsula". Bull. Fac. Fish. Hokkaido Univ., **7** (4): 284–89. Hakodate, 1957.

Worthington, L. V., & Schevill, W. E. "Underwater sounds heard from sperm whales". Nature, **180** (4580): 291. London, 1957.

1) e General Apparatus

Anon. "Fish behaviour in cod ends studied with underwater television (M/V 'Albatross III', Cruise 96)". Commerc. Fish. Rev., **19** (8): 29. Washington, 1957.

McAllister, R. F. "Photography of submerged vertical structures". Trans. American Geophys. Union, **38** (3): 314–19. Washington, 1957.

Riedl, R. "Automatische Photographie von Meeresböden für ökologisch-faunistische Zwecke". Österreichische Zool. Zeitschr., **6** (3/5): 532–41. Wien, 1956.

Sand, R. F. "New diving sled". Commerc. Fish. Rev., **18** (10): 6–7. Washington, 1956.

Sasaki, T., *et al.* "Investigation of the sea floor of Tsugaru Straits by under-water camera". Rec. Oceanogr. Works Japan, **3** (1): 56–69. Tokyo, 1957.

Taylor, H. J. "Underwater swimming and diving". Nature, **180** (4592): 883–86. London, 1957.

2) Physical Oceanography

2) a Practical Aspects

ANON. "Marine climatic atlas of the world. Vol. 1. North Atlantic Ocean". NAVAER 50–IC–528, Chief of Naval Operations, Washington, 1955.

ANON. "Flotteurs-témoins de courant. Huitième liste de flotteurs récupérés". Bull. Inform. (COEC), **8**: 464–67. Paris, 1957.

ANON. "Observations hydrologiques. A. Bâtiments de la Marine Nationale. B. Navires météorologiques stationnaires". Bull. Inform. (COEC), **9**: 521–30. Paris, 1957.

ANON. "Observations hydrologiques des bâtiments de la Marine Nationale: a) 'Beautemps-Beaupré' (Baie Corisco, Gabon, 1955); b) 'Lapérouse' (Océan Indien, 1956); c) 'Ellie-Monnier' (Méditerranée occidentale, 1956)". Bull. Inform. (COEC), **9** (10): 579–88. Paris, 1957.

ANON. "Data record of oceanographic observations and exploratory fishing. No. 1". Fac. Fish. Hokkaido Univ., Hakodate, 1957.

ANON. "Bulletin hydrographique pour l'année 1953". ICES, Copenhague, 1957.

ANON. "Echo sounding corrections (USSR delegation)". Internat. Hydrogr. Rev., **34** (2): 35–39. Monaco, 1957.

ANON. "Année Géophysique Internationale. Working Group on Oceanography of CSAGI Göteborg Meeting, 15–17 January 1957". IUGG Chronicle, **2**: 39–62. Paris, 1957.

ANON. "Research vessel 'Ernest Holt' hydrographical observations 1952". MAFF, Lowestoft, 1957.

ANON. "Research vessel 'Ernest Holt' hydrographical observations 1955". MAFF, Lowestoft, 1957.

ANON. "Climatological charts of the North Atlantic. May October, 1957". Meteorol. Off., London, 1957.

ANON. "Observations hydrologiques des bâtiments de la Marine Nationale. Escorteur l'Aventure' (Atlantique Nord, 1956)". Bull. Inform. (COEC), **10** (1): 29–41. Paris, 1958.

BURKOV, V. A., *et al.* "Techniques of hydrographic work in the open sea". Trans. Inst. Oceanol., **24**:5. Moscow, 1957.

BURMISTER, C. A. "Electronics in hydrographic surveying. I. How deep is the ocean". Internat. Hydrogr. Rev., **34** (2): 117–25. Monaco, 1957.

GORSHKOVA, T. I., *et al.* "Finnish-Soviet oceanographical and biological investigations in the Baltic Sea". Rybn. Khoz., 1957 (3): 42–48. Moscow, 1957.

HOFFMAN, J. "Hyperbolic curves applied to echo sounding". Internat. Hydrogr. Rev., **34** (2): 45–55. Monaco, 1957.

LUMBY, J. R., & SAELEN, O. H. "Report on oceanographical work from Ocean Weather Ships". Publ. Sci. Assoc. Océanogr. Phys., Union Géodés. et Géophys. Internat., **16**. Göteborg, 1957.

MOTODA, S. "Hydrographic data obtained principally in the Bering Sea by training ship 'Oshoro Maru' in the summer of 1955". Fac. Fish. Hokkaido Univ., Hakodate, 1956.

NAKANO, M. "Some oceanographical instruments recently devised in Japan". Misc. Geofis., Serv. Meteorol. Angola Comem. X Aniv. Serv. Meteorol. Nacion.: 206–22. Luanda, 1956.

ROCHFORD, D. J., & SPENCER, R. S. "Onshore and oceanic hydrological investigations in eastern and south-western Australia, 1956". CSIRO, Oceanogr. Stat. List, **30**. Melbourne, 1957.

ROCHFORD, D. J., & SPENCER, R. S. "Surface sampling in the Tasman and Coral Seas and the south-eastern Indian Ocean, 1956". CSIRO, Oceanogr. Stat. List, **31**. Melbourne, 1957.

SCHULER, F. "Echogram profiles and how they can be established". Internat. Hydrogr. Rev., **34** (2): 41–44. Monaco, 1957.

DA SILVA, P. M. "Some new methods for the rapid processing of oceanic data". Internat. Hydrogr. Rev., **34** (2): 137–40. Monaco, 1957.

TROTTI, L. "Tables of the specific volume in situ for Mediterranean waters with an appendix of the $2\omega \sin \varphi$ for the same area". Atti Accad. Lig. Sci. e Lett., **12**: 39–60. Genova, 1956.

2) c Submarine Topography

AYBULATOV, N. A. "A method for determining the thickness of streams of suspended sand alluvium along the sea-shore". Doklady Akad. Nauk SSSR, **116** (2): 281. Moscow, 1957.

Berthois, L., & Brenot, R. "Topographie sous-marine de l''Outer Silver Pit' et du 'Markhams Hole' Lat. N. 54°, Long. E. Gr. 2°". Rev. Trav. Inst. Pêches Marit., **21** (3): 431–34. Paris, 1957.

Berthois, L., & Brenot, R. "Note préliminaire sur la topographie du talus du plateau continental dans le Golfe de Gascogne". Rev. Trav. Inst. Pêches Marit., **21** (3): 435–37. Paris, 1957.

Bezrukov, P. L., *et al.* "New data on the regularities of the morphology of submarine relief". Doklady Akad. Nauk SSSR, **116** (5): 841. Moscow, 1957.

Blanc-Vernet, L. "Remarques sur les foraminifères de l'Herbier à Posidonies". Rec. Trav. Stat. Mar. Endoume, **22**: 95–101. Marseille, 1957.

Boldyrev, V. L. "Type of coast with ancient slump- and slide phenomena". Trudy Inst. Okeanol. Akad. Nauk SSSR, **21**: 118–32. Moscow, 1957.

Cartwright, D., & Stride, A. H. "Large sand waves near the edge of the continental shelf". Nature, **181** (4601): 41. London, 1958.

Cloet, R. L. "Sandwaves in the southern North Sea and in the Persian Gulf". J. Inst. Navig., **7**: 272–79. London, 1954.

Crary, A. P., & Goldstein, N. "Geophysical studies in the Arctic Ocean". Deep-Sea Res., **4** (3): 185–201. London & New York, 1957.

Devdariani, A. S. "Methods of direct measurement of the thickness of the alluvial layer and sedimentation". Izvest. Akad. Nauk SSSR, Ser. Geogr., 1956 (4): 103. Moscow, 1956.

Duboul-Razavet, C. "Etude sédimentologique du Cap Peloro (Détroit de Messine)". Rec. Trav. Stat. Mar. Endoume, **22**: 83–94. Marseille, 1957.

Durand, J. H. "Etude pétrographique de quelques vases draguées au large de Tighzirt et au large de Castiglione". Trav. Stat. Aquicult. et Pêche Castiglione, N.S., **8**: 41–56. Castiglione, 1957.

Fridman, R. "Sur des amas périodiques de matériel plus grossier à la surface de certaines plages sableuses". Bull. Inform. (COEC), **9**: 508–10. Paris, 1957.

Goel, P. S., *et al.* "The beryllium-10 concentration in deep-sea sediments". Deep-Sea Res., **4** (3): 202–10. London & New York, 1957.

Grousson, R. "Bathymétrie de la côte Atlantique du Maroc". Bull. Inform. (COEC), **8**: 411–13. Paris, 1957.

Guilcher, A. "Quelques aspects et problèmes morphologiques et sédimentologiques de l'île d'Ouessant". Norois, **4** (15). Poitiers, 1957.

Hamaguchi, H., Tatsumoto, M., & Itaya, J. "Chemical investigations of deep-sea deposits, XIX". J. Chem. Soc. Japan, Pure Chem. Sect., **75**: 119–21. Tokyo, 1954.

Hill, M. N. "Bathymetric chart of the N.E. Atlantic". IUGG Chronicle, **4**: 142–43. Paris, 1957.

Kolbe, R. W. "Fresh-water diatoms from Atlantic deep-sea sediments". Science, **126** (3282): 1053–56. Lancaster, Pa., 1957.

Medvedev, V. S., & Aibulatov, N. A. "The use of 'marked' sands in studying the process of marine sediments". Izvest. Akad. Nauk SSSR, Ser. Geogr., 1956 (4): 99. Moscow, 1956.

Miller, R. L. "Trend surfaces: their application to analysis and description of environments of sedimentation. I. The relation of sediment-size parameters to current-wave systems and physiography". J. Geol., **64** (5): 425–46. Chicago, 1956.

Muraour, P. "Sédiments et sédimentation au large de la région située entre le Cap Tedlès et la Pointe de l'Ait-Raouna (Est de Tighzirt)". Trav. Stat. Aquicult. et Pêche Castiglione, N.S., **8**: 29–39. Castiglione, 1957.

Odum, H. T. "Biogeochemical deposition of strontium". Publ. Inst. Mar. Sci., **4** (2): 38–114. Port Aransas, Texas, 1957.

Orr, W. L., & Grady, J. R. "Determination of chlorophyll derivatives in marine sediments". Deep-Sea Res., **4** (4): 263–71. London & New York, 1957.

Pinto, J. S. "Contribuição para o estudo dos foraminiferos dos sedimentos marinhos de Angola". Trab. Miss. Biol. Marit., 1955 (16): 193–230. Lisboa, 1957.

Plunkett, M. A. "The qualitative determination of some organic compounds in marine sediments". Deep-Sea Res., **4** (4): 259–62. London & New York, 1957.

Robinson, A. H. W. "The submarine morphology of certain port approach channel systems". J. Inst. Navig., **9** (1): 20–46. London, 1956.

Rouch, J. "La composition du fond de la mer. Les instruments modernes pour son étude". Scientia, Ser. 6, **90** (523): 345–50. Milano, 1955.

Semenovich, N. I. "On oxygen absorption by lake-muds". Doklady Akad. Nauk SSSR, **115** (1): 130. Moscow, 1957.
Shepard, F. P. "Texas Bay sediments". Publ. Inst. Mar. Sci., **4** (2): 5–13. Port Aransas, Texas, 1957.
van Straaten, L. M. J. U., & Kuenen, P. H. "Accumulation of fine grained sediments in the Dutch Wadden Sea". Geol. en Mijnbouw, 1957 (August). Holland, 1957.
Sutton, G. H., Berckhemer, H., & Nafe, J. E. "Physical aspects of deep-sea sediments". Trans. American Geophys. Union, **38** (3): 407. Washington, 1957.
Sverdrup, H. U. "The existence of a submarine ridge crossing the Polar Sea, predicted by J. E. Fjeldstad in 1936". Norsk Geogr. Tidsskr., **15** (1–2). Oslo, 1955.
Turekian, K. K. "The significance of variations in the strontium content of deep sea cores". Limnol. & Oceanogr., **2** (4): 309–14. Baltimore, 1957.
Wüst, G. "Grösste Meerestiefen in den Ozeanen und verschiedenen Nebenmeeren". Geogr. Taschenbuch, 1956/57: 256. Wiesbaden, 1956.
Zenkovich, V. P. "Investigations on the bottom-shifting of sands". Trudy Inst. Okeanol. Akad. Nauk SSSR, **21**: 40–46. Moscow, 1957.
Zenkovich, V. P. "On the selection of shore-debris at the tip of marine spits". Trudy Inst. Okeanol. Akad. Nauk SSSR, **21**: 133–36. Moscow, 1957.

2) d Sea Water, Physics

Anon. "Two modifications of the secchi disk". Progr. Fish-Cult., **19** (4): 167. Washington, 1957.
Cox, R. A. "An improved salinity and density meter". ICES, J. Cons., **23** (1): 38–46. Copenhague, 1957.
Fedorov, K. N. "On the calculation of the field of density in the ocean". Izvest. Akad. Nauk SSSR, Ser. Geofiz., 1956 (9): 1068. Moscow, 1956.
Grousson, R. "La propagation du son dans le chenal sonore". Ann. Hydrogr., **4** (6): 353–69. Paris, 1956.
Grousson, R. "Cours de radioélectricité et d'acoustique sous-marine". Serv. Centr. Hydrogr., Ecole d'Applic., **7**. Paris, 1956–1957.
Hubbard, C. J. "A wide-range, high speed bathyphotometer". Techn. Rep. Woods Hole Oceanogr. Inst., **56–68**. Woods Hole, 1956.
Hudimac, A. A. "Ray theory solution for the sound intensity in water due to a point source above it". J. Acoust. Soc. America, **29**: 916–17. Menasha, Wis., 1957.
Ivanoff, A. "Au sujet de la pénétration de la lumière dans la mer". CR Acad. Sci., **241** (22): 1612. Paris, 1955.
Ivanoff, A. "Un polarimètre sous-marin à cellule photoélectrique. Premiers résultats obtenus". Bull. Inform. (COEC), **9**: 491–99. Paris, 1957.
Ivanoff, A. "Contribution à l'étude des propriétés optiques de l'eau de mer en Bretagne et en Corse, et à la théorie de la polarisation sous-marine". Ann. Géophys., **13** (1). Paris, 1957.
Kampa, E. M. "A discrepancy between calculation and measurement of submarine illumination". Proc. Nation. Acad. Sci., **41** (11): 938–39. Washington, 1955.
Lenoble, J. "Spectromètre photoélectrique sous-marin". Bull. Inform. (COEC), **9** (10): 551–64. Paris, 1957.
Martin, A. V. J. "Essai d'interprétation physique de la couche diffusante profonde. (D.S.L.)". Bull. Inform. (COEC), **9**: 483–90. Paris, 1957.
Panov, D. G. "Certain peculiarities in the tectonic of the bordering parts of the Pacific platform". Doklady Akad. Nauk SSSR, **115** (1): 157. Moscow, 1957.
Sagar, F. H. "Comparison of experimental underwater acoustic intensities of frequency 14.5 kc with values computed for selected thermal conditions in the sea". J. Acoust. Soc. America, **29**: 948–65. Menasha, Wis., 1957.
Sasaki, T., *et al.* "Optical properties of the water in the Kuroshio current (II)". Rec. Oceanogr. Works Japan, **3** (1): 92–103. Tokyo, 1957.
Sasaki, T., *et al.* "Measurements of the angular distribution of daylight in the sea". Rec. Oceanogr. Works Japan, Spec. No. Oceanogr. Res. Proj. Japanese Nation. Commiss. UNESCO: 42–45. Tokyo, 1957.
Schenck, H. "On the focusing of sunlight by ocean waves". J. Optic. Soc. America, **47**: 653–57. New York, 1957.
Sheehy, K. J., & Halley, R. "Measurement of the attenuation of low-frequency underwater sound". J. Acoust. Soc. America, **29**: 464–69. Menasha, Wis., 1957.

Urick, R. J., Pharo, L. C., & Skudrzyk, E. "A new method for measuring the thermal microstructure of the sea". Trans. American Geophys. Union, **38** (3): 410. Washington, 1957.

Usami, T. "The reflection and refraction of elastic waves at sea bottom". Geophys. Mag., **27** (1): 77. Tokyo, 1956.

Uusitalo, S. "On the interpretation of bathythermograms". Geophysica, **5** (3). Helsinki, 1957.

Volkov, V. G., & Shekhvatov, B. V. "Acoustical coupled high-speed bathythermograph". Trans. Inst. Oceanol., **24**: 215. Moscow, 1957.

Wagner, N. K. "A description of a micro-meteorological and oceanographic measurement program in conjunction with radio propagation tests over the Gulf of Mexico". Trans. American Geophys. Union, **38** (3): 411. Washington, 1957.

Welander, P. "On the self-sustained oscillations of a simple thermal system". Tellus, **9** (3): 419–22. Stockholm, 1957.

Yoshida, K. "A note on the pressure changes of the two-layer ocean". Geophys. Notes, **10** (1). Tokyo, 1957.

2) e Sea Water, Chemistry

Acara, A. "On the use of a shaking-machine for salinity analysis". Hidrobiol., Ser. B, **4** (2–3): 108–09. Istanbul, 1957.

Anon. "Air and water pollution. The position in Europe and in the United States. (Project Nos. 136 and 145)". HMSO, London, 1957.

Armstrong, F. A. J. "The iron content of sea water". J. Mar. Biol. Assoc., **36** (3): 509–17. Cambridge, 1957.

Boguslavsky, S. G. "The dependence of the turbulence factor on the sea wave parameters". Doklady Akad. Nauk SSSR, **115** (3): 494. Moscow, 1957.

Bowen, V. T., & Sugihara, T. T. "Strontium 90 in North Atlantic surface water". Proc. Nation. Acad. Sci., **43** (7): 576–80. Washington, 1957.

Buljan, M. "Deep submarine volcanisms and the chemistry of ocean". Bull. Volcanol., UGGI Internat., Ser. 2, **17**. Paris, 1955.

Burton, J. D., & Riley, J. P. "Germanium and gallium in sea-water-germanium". Nature, **181** (4603): 179. London, 1958.

Carpenter, J. H. "The determination of calcium in natural waters". Limnol. & Oceanogr., **2** (3): 271–80. Baltimore, 1957.

Corner, E. D. S., & Rigler, F. H. "The loss of mercury from stored sea-water solutions of mercuric chloride". J. Mar. Biol. Assoc., **36** (3): 449–58. Cambridge, 1957.

Cox, R. A. "An improved salinity and density meter". ICES, J. Cons., **23** (1): 38–46. Copenhague, 1957.

Culkin, F., & Riley, J. P. "Germanium and gallium in sea-water-gallium". Nature, **181** (4603): 180. London, 1958.

Hastings, W. W., *et al.* "Report of the Committee on Chemistry of Natural Waters, 1952–1953". Trans. American Geophys. Union, **35** (6): 974–78. Washington, 1954.

Inglis, C. C. "Radio-frequency salinity meter". Hydraulics Res., 1955: 52. London, 1956.

Inoue, N., & Fukuda, M. "Report from the 'Oshoro Maru' on oceanographic and biological investigations in the Bering Sea and northern North Pacific in the summer of 1955. II. Radioactivity of sea water". Bull. Fac. Fish. Hokkaido Univ., **7** (3): 233–35. Hakodate, 1956.

Ishibashi, M., Shigematsu, T., & Nishikawa, Y. "The amount of beryllium in sea water". Bull. Inst. Chem. Res. Kyoto Univ., **34** (4): 210–13. Kyoto, 1956.

Ishibashi, M., & Tabushi, M. "Quantitative analysis of phosphoric acid. VII. Concentration of trace amounts of phosphate in a dilute solution or in sea water by co-precipitation with magnesium hydroxide". Japan Analyst, **6** (1): 7–10. Tokyo, 1957.

Kahn, B., Smith, D. K., & Straub, C. P. "Determination of low concentrations of radioactive caesium in water". Analyt. Chem., **29** (8): 1210–13. Washington, 1957.

Koczy, F. F., Picciotto, E., Poulaert, G., & Wilgain, S. "Determination of thorium isotopes in sea water". Geochim. et Cosmochim. Acta **11**: 103–29. London, 1957.

Kume, T., Kuno, T., & Tanaka, T. "Studies on the direct manufacture of sodium hydroxide and other materials from sea water. Part 3. Effects of co-existing ions for electrolysis". Rec. Oceanogr. Works Japan, Spec. No. Oceanogr. Res. Proj. Japanese Nation. Commiss. UNESCO: 50–52. Tokyo, 1957.

Kume, T., & Okada, M. "Studies on the direct manufacture of sodium hydroxide and other materials from sea water. Part 2. Electrolysis by mercury process using a diaphragm". Rec. Oceanogr. Works Japan, Spec. No. Oceanogr. Res. Proj. Japanese Nation. Commiss. UNESCO: 53–56. Tokyo, 1957.

Kume, T. "Studies on the direct manufacture of sodium hydroxide from sea water". Rec. Oceanogr. Works Japan, Spec. No. Oceanogr. Res. Proj. Japanese Nation. Commiss. UNESCO: 57. Tokyo, 1957.

Liebmann, H. "Abwasserbeseitigung in Küstengebieten und ihr Einfluss auf die Fischerei". Fischwirtschaft, **7** (11): 303–05. Bremerhaven, 1955.

Marvin, K. T. "A device for rapid conversion of titration values to salinity". Limnol. & Oceanogr., **2** (4): 371–74. Baltimore, 1957.

Matsudaira, C., & Tsuda, T. "Studies on the analytical method of ammonia and organic nitrogen in sea water". Tohoku J. Agric. Res., **8** (1): 37–45. Sendai, 1957.

Nagai, M. "A note on the annual variation of dissolved oxygen in sea water. Parts 1 & 2". Oceanogr. & Meteorol., **7** (1/4). Nagasaki, 1956.

Odum, H. T. "Strontium in natural waters". Publ. Inst. Mar. Sci., **4** (2): 22–37. Port Aransas, Texas, 1957.

Sandels, E. G. "An instrument for the measurement of salinity in estuaries". J. Sci. Instrum., **33**: 424–28. London, 1956.

Spencer, C. P. "The oxidation of ammonia in the sea". Challenger Soc., **3** (9): 21. London, 1957.

Taga, N. "Studies on water pollution problems by the wastes from the preparation of coal and ore". Aquiculture Ser., Fish. Agency Japan, **4**: 1–60. Japan, 1955.

Westland, A. D., & Langford, R. R. "Determination of nitrate in fresh water. Concentration of samples by an ion exchange procedure". Analyt. Chem., **28**: 1996. Washington, 1956.

Yamagata, N. "Separation of a trace amount of caesium by ion-exchange chromatography. A preliminary study for the determination of caesium in sea water". J. Chem. Soc. Japan, Pure Chem. Sect., **78** (4): 513–17. Tokyo, 1957.

Yoshizawa, K. "Influence of silicic acid on the determination of phosphoric acid in water". Nippon Jôzô Kyôkai Zasshi, **51**: 531–34. 1956.

2) f Structure, Dynamics, and Circulation

Abe, T. "A study on the foaming of sea water (10). On the analogy between the coagulation process of colloidal particles and that of bubbles in foam layer of sea water". Collect. Repr. Oceanogr. Lab. Meteorol. Res. Inst. Tokyo, **3**. Tokyo, 1956.

Abe, T. "A study on the foaming of sea water. A tentative analysis of wind wave date in view of the foaming of sea water (II)". Pap. Meteorol. & Geophys., 7 (2). Tokyo, 1956.

Anon. "Klimatologie der nordwesteuropäischen Gewässer. Teil 3. Tabellen-Anhang: Wasseroberflächentemperatur; Streuung der Wassertemperatur; Temperaturdifferenz Luft minus Wasser". Deutsche Wetterdienst Seewetteramt, 1956 (10). 1956.

Bailey, W. B. "Oceanographic features of the Canadian Archipelago". J. Fish. Res. Board Canada, **14** (5): 731–69. Ottawa, 1957.

Barber, F. G. "Observations of currents north of Triangle Island, B. C." Fish. Res. Board Canada, Progr. Rep. Pacific Coast Stat., **108**: 15–18. Nanaimo, 1957.

Barber, F. G. "The effect of the prevailing winds on the inshore water masses of the Hecate Strait region, B.C." J. Fish. Res. Board Canada, **14** (6): 945–52. Ottawa, 1957.

Barnes, C. A., & Paquette, R. G. "Circulation near the Washington coast (48°N., 128° W.)". Techn. Rep. Dept. Oceanogr. Univ. Washington, **17**. Washington, 1954.

Bloom, G. L. "Current, temperature, tide, and ice growth measurements, eastern Bering Strait – Cape Prince of Wales, 1953–55". USN Electronics Lab., Res. Rep., **739**. USA, 1956.

Bossolasco, M., Cavo, A., & Dagnino, I. "Sulla genesi dei microsismi". Geofis. Pura e Applic., **38**. Milano, 1957.

Bossolasco, M., & Dagnino, I. "Sulla turbolenza delle correnti marine nello Stretto di Messina". Geofis. Pura e Applic., **37**: 318–24. Milano, 1957.

Bumpus, D. F., *et al.* "A new technique for studying non-tidal drift with results of experiments off Gay Head, Mass., and in the Bay of Fundy". J. Fish. Res. Board Canada, **14** (6): 931–44. Ottawa, 1957.

Gagniard, L. "Sur la théorie de la mesure électromagnétique des courants marins". Ann. Géophys., **13** (2). Paris, 1957.

Charney, J. G. "The Gulf Stream as an inertial boundary layer". Proc. Nation. Acad. Sci., **41** (10): 731. Washington, 1955.

Chew, F., Wagner, L. P., & Work, R. C. "Heat transport of the Florida Current". Techn. Rep. Univ. Miami Mar. Lab., **57–21**. Coral Gables, Fla., 1957.

Craig, R. E. "Recent changes in the North Sea herring fisheries. Appendix II. Recent hydrographic changes in the north-western North Sea". ICES, R. et P.–V., **143** (1): 25. Copenhague, 1957.

Dat, J. "Remarque sur les mesures par flotteur du déplacement d'un plan d'eau". CR Acad. Sci., **245** (5). Paris, 1957.

Dobrzhanskaya, M. A. "Seasonal peculiarities in the vertical distribution of oxygen within the zone of photosynthesis in the Black Sea". Doklady Akad. Nauk SSSR, **115** (4): 755. Moscow, 1957.

Dunbar, M. J. "The present status of climatic change in the Atlantic sector of northern seas, with special reference to Canadian eastern arctic waters". Trans. Roy. Soc. Canada, Ser. 3, **49**: 1–7. Ottawa, 1955.

Evans, F. "Sea currents off the Northumberland coast". J. Mar. Biol. Assoc., **36** (3): 493–99. Cambridge, 1957.

Federov, K. N. "On yearly and half-year fluctuations of the general circulation in oceans". Doklady Akad. Nauk SSSR, **116** (3): 393. Moscow, 1957.

Gorbunov, J. A. "Sur l'échange d'eau entre la mer de Sibérie orientale et la mer des Tchoucktchis à travers le détroit de Long". Inst. Rech. Sci. Arctique, Edit. Etat "Transport maritime", Problèmes Arctiques, **1**. Leningrad, 1957.

Graham, J. J. "Central North Pacific albacore surveys, May to November 1955". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **212**. Washington, 1957.

Hela, I. "Longitudinal and transversal slope of the Florida current". Geophysica, **5** (3). Helsinki, 1957.

Hidaka, K. "Geostrophic currents and mixing". Geophys. Notes, **10** (1). Tokyo, 1957.

Hidaka, K. "Influence of friction on geostrophic flow: sources of errors in dynamic computation of ocean currents". Geophys. Notes, **10** (1). Tokyo, 1957.

Hill, H. W., & Lee, A. J. "The effect of wind on water transport in the region of the Bear Island fishery". Proc. Roy. Soc., Ser. B, **148** (930): 104–16. London, 1958.

Horsted, S. A., & Smidt, E. "The deep sea prawn (*Pandalus borealis* Kr.) in Greenland waters". Medd. Danmarks Fisk.- og Havunders., NS, **1** (11). København, 1956.

Ichiye, T. "A note on the horizontal eddy viscosity in the Kuroshio". Rec. Oceanogr. Works Japan, **3** (1): 16–25. Tokyo, 1957.

Kamenkovich, V. M. "On the influence of the relief of the bottom on a pure drift current in an homogeneous shoreless sea". Izvest. Akad. Nauk SSSR, Ser. Geofiz., 1956 (10): 1182. Moscow, 1956.

Kasahara, S. "Some considerations regarding the use of drift envelopes for the investigation of surface ocean currents, with special reference to their quality as compared with that of drift bottles". Ann. Rep. Japan Sea Reg. Fish. Res. Lab., **3**: 155–66. Niigata, 1957.

Keulegan, G. H. "Eighth progress report on model laws for density currents: significant stresses of arrested saline wedges". Rep. Nation. Bur. Stand., **4267**. Washington, 1955.

Koizumi, M. "Researches on the variations of oceanographic conditions in the region of the Ocean Weather Station 'Extra' in the North Pacific Ocean. (2). Air temperature, sea surface temperature, and wind. (3). The variation of hydrographic conditions discussed from the heat balance point of view and the heat exchange between sea and atmosphere". Pap. Meteorol. & Geophys., **6** (3/4): 261 & 273. Tokyo, 1956.

Krauss, W. "Das Zirkulationstheorem von V. Bjerknes und seine Anwendung in der Ozeanographie". Deutsche Hydrogr. Zeitschr., **10** (1): 13–19. Hamburg, 1957.

Lauzier, L. "Effect of storms on the water conditions in the Magdalen Shallows". Bull. Fish. Res. Board Canada, **111**: 185–92. Ottawa, 1957.

Lauzier, L. "The St. Lawrence spring run-off and summer salinities in the Magdalen Shallows". Bull. Fish. Res. Board Canada, **111**: 193–94. Ottawa, 1957.

Lauzier, L. "Bottom temperatures on the Magdalen Shallows". Bull. Fish. Res. Board Canada, **111**: 269–85. Ottawa, 1957.

Lauzier, L. "Variations of temperature and salinity in shallow waters of the southwestern Gulf of St. Lawrence". Bull. Fish. Res. Board Canada, **111**: 251–68. Ottawa, 1957.

Lauzier, L. "Hydrographic features of the waters of the Bay of Islands, Newfoundland, in the autumn". Bull. Fish. Res. Board Canada, **111**: 287–317. Ottawa, 1957.

Lauzier, L., & Bailey, W. B. "Features of the deeper waters of the Gulf of St. Lawrence". Bull. Fish. Res. Board Canada, **111**: 213–50. Ottawa, 1957.

Lauzier, L., Trites, R. W., & Hachey, H. B. "Some features of the surface layer of the Gulf of St. Lawrence". Bull. Fish. Res. Board Canada, **111**: 195–212. Ottawa, 1957.

Lineikin, P. S. "On winter currents in a deep sea". Meteorol. i Gidrol., 1956 (12): 26–33. Leningrad, 1956.

Lineikin, P. S. "On steady wind-driven currents and the distribution of density in a deep sea". Doklady Akad. Nauk SSSR, **116** (3): 389. Moscow, 1957.

Lizeray, J. C. "Travaux océanographiques récents de l''Elie Monnier' en Méditerranée occidentale". Bull. Inform. (COEC), **9** (8): 413–15. Paris 1957.

MacGregor, D. G. "Calculation of geostrophic currents". Atlantic Oceanogr. Group, St. Andrews, 1956.

Mandelbaum, H., Lawford, A. L., & Veley, V. F. C. "Evidence for a critical wind velocity for air-sea boundary processes. Change in the relationship between wind and surface water movement at higher wind speeds". Trans. American Geophys. Union, **38** (4): 584–86. Washington, 1957.

Masuzawa, J. "An example of cold eddies south of the Kuroshio. Currents and water masses of the Kuroshio sytem. VII". Rec. Oceanogr. Works Japan, **3** (1): 1–7. Tokyo, 1957.

Menendez, N. "Mémorandum sur l'étude de la circulation à travers les détroits". IUGG Chronicle, **2**: 68–71. Paris, 1957.

Metallo, A. "Il sistema meteo-oceanografico del Mediterraneo". Boll. Soc. Geogr. Italiana, Ser. 8, **9** (6/8): 345. Roma, 1956.

Muromtsew, A. M. "Patterns of annual temperature run in the surface layer of the ocean". Doklady Akad. Nauk SSSR, **116** (5): 776. Moscow, 1957.

Nan'niti, T. "On the structure of ocean currents (II). The turbulent fluctuations in a tidal current". Pap. Meteorol. & Geophys., **7** (2). Tokyo, 1956.

Nikiforov, E. G. "On the connection between currents and waves produced by wind". Izvest. Akad. Nauk SSSR, Ser. Geofiz., 1956 (12): 1450. Moscow, 1956.

Noodt, E. "Temperatur- und Salzgehaltsanomalien in Tiefenhorizonten des Atlantischen Ozeans". Dissert. Christian-Albrechts-Univ. Kiel, Kiel, 1955.

Passega, R. "Turbidity currents petroleum exploration". Bull. American Assoc. Petrol. Geol., **38**: 1871–87. Tulsa, Okl., 1954.

Pritchard, D. W., Todd, D. K., & Lau, L. "On estimating streamflow into tidal estuary". Trans. American Geophys. Union, **38** (4): 581–84. Washington, 1957.

Reid, R. O. "Modification of the quadratic bottom-stress law for turbulent channel flow in the presence of surface wind-stress". Techn. Mem. Beach Erosion Board, **93**. Washington, 1957.

Saint-Guily, B. "Les méandres de veines de courant dans les océans". Bull. Inst. Océanogr., **1108**. Monaco, 1957.

Schemainda, R. "Die hydrographischen Veränderungen im Bornholmtief durch den grossen Salzwassereinbruch im Dezember 1951". Halle/Saale, 1955.

Schemainda, R. "Über den Einfluss der meteorologisch-hydrographischen Bedingungen auf die Fischerei in den Gewässern um Grönland". Deutsche Fisch. Zeit., 1957 (4): 98–105. Radebeul, 1957.

Schulz, H. "Die Characterisierung von Sturmfluten an den Küsten von Tidemeeren". Wasser u. Boden, **8** (10): 337. 1956.

Selitskaya, E. S. "On the question of internal waves". Meteorol. i Gidrol., 1957 (6): 35. Leningrad, 1957.

Stommel, H. "A survey of ocean current theory". Deep-Sea Res., **4**: 149–84. London & New York, 1957.

Stommel, H., & Veronis, G. "Steady convective motion in a horizontal layer of fluid heated uniformly from above and cooled non-uniformly from below". Tellus, **9** (3): 401–07. Stockholm, 1957.

Sysoev, N. N., & Volkov, V. G. "Manual of the techniques of electromagnetic measurement of sea currents velocities under way". Trudy Inst. Okeanol., Akad. Nauk SSSR, **24**: 173. Moscow, 1957.

Tabata, S. "Heat exchange between sea and atmosphere along the northern British Columbia coast". Fish. Res. Board Canada, Progr. Rep. Pacific Coast Stat., **108**: 18–20. Nanaimo, 1957.

Tait, J. B. "Hydrography of the Faroe-Shetland Channel 1927–1952". Scottish Home Dept., Mar. Res., 1957 (2). Edinburgh, 1957.

Takano, K. "Influence des échanges thermiques, de la précipitation et de l'évaporation sur la circulation générale dans les océans". CR Acad. Sci., **242** (18): 2245. Paris, 1956.
Tambs-Lyche, H. "Daily observations of surface temperature and salinity at the biological station during 1951 and 1952". Univ. Bergen, Årbok, 1957 (7). Bergen, 1957.
Tchernia, P. "L'eau intermédiaire dans le bassin algéro-provençal". Bull. Inform. (COEC), **10** (1): 19–22. Paris, 1958.
Timofeev, V. T. "Sur la formation des eaux de fond de la partie centrale du bassin arctique". Inst. Rech. Sci. Arctique, Edit. Etat "Transport maritime", Problèmes Arctiques, **1**. Leningrad, 1957.
Turekian, K. K. "Salinity variations in sea water in the vicinity of Bimini, Bahamas, British West Indies". American Mus. Novit., **1822**: 1–12. New York, 1957.
Uyguner, B. "Le dosage du nitrite dans les eaux du Bosphore, Dardanelles et Trébizonde. Considérations sur la production biologique du nitrite et le cycle d'azote". Hidrobiol., Ser. B, **4** (2–3): 50–61. Istanbul, 1957.
Valentine, B., & McCleskey, C. S. "Oxidation-reduction potentials of the water and sediments of Barataria Bay, Louisiana (29°N., 90°W.)". Bull. Mar. Sci. Gulf & Caribbean, **6** (3): 200. Coral Gables, Fla., 1956.
Wangersky, P. J., & Hutchinson, G. E. "Manganese deposition and deep water movements in the Caribbean". Nature, **181** (4602): 108. London, 1958.
Wertheim, G. K. "Studies of the electric potential between Key West, Florida, and Havana, Cuba". Trans. American Geophys. Union, **35** (6): 872–82. Washington, 1954.
Wüst, G. "The 'Meteor' profiles in the Atlantic". IUGG Chronicle, **2**: 81–83. Paris, 1957.
Wyrtki, K. "Die Zirkulation an der Oberfläche der südostasiatischen Gewässer". Deutsche Hydrogr. Zeitschr., **10** (1): 1–13. Hamburg, 1957.
Yasui, M. "On the rapid estimation of the dynamic topography in the seas adjacent to Japan". Rec. Oceanogr. Works Japan, **3** (1): 8–15. Tokyo, 1957.
Yeo, S.-A. "The problem of wind drift near a free water surface". Challenger Soc., **3** (9): 35. London, 1957.

2) g Waves, Tides, and Sea-Level

Abe, T. "A study on the foaming of sea water: a tentative analysis of wind wave data in view of the foaming of sea water (II)". Pap. Meteorol. Geophys., **7**: 136–43. Tokyo, 1956.
Anon. "New scales of sea and swell". IUGG Chronicle, **2**: 78–79. Paris, 1957.
Anon. "Bibliography on tides 1940–1954". Publ. Sci. Assoc. Océanogr. Phys., Union Géodés. et Géophys. Internat., **17**. Göteborg, 1957.
Bossolasco, M. "Alcuni caratteri del moto ondoso et la maregiatta eccezionale nel golfo di Genova del 19 febraio 1955". Geofis. e Meteorol., **3** (6). Genova, 1955.
Chien, N. "Ripple tank studies of wave refraction". Trans. American Geophys. Union, **35** (6): 897–904. Washington, 1954.
Cote, L. J. "Short-time prediction of sea surface height: prediction of a degenerate stochastic process". Counc. on Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.
Darbyshire, J. "Attenuation of swell in the North Atlantic Ocean". Quart. J. Roy. Meteorol. Soc., **83** (357): 351–59. London, 1957.
Darbyshire, J., & Darbyshire, M. "The refraction of microseisms on approaching the coast of the British Isles". Monthly Not. Roy. Astron. Soc., Geophys. Suppl., **7** (6): 301–07. London, 1957.
Deacon, G. E. R., Russell, R. C. H., & Palmer, J. E. G. "Origin and effects of long period waves in ports". 19th Internat. Nav. Congr., Sect. II, Ocean Navig., Commun. 1, S. II–C.1. Brussels, 1957.
Disney, L. P. "Tide heights along the coasts of the United States". Proc. American Soc. Civil Engin., **81** (666). New York, 1955.
Doodson, A. T. "Tidal movement". Internat. Hydrogr. Rev., **34** (2): 135. Monaco, 1957.
Farmer, H. G., *et al.* "A technique for ocean wave measurements". Counc. on Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.
Fichot, E. "Contribution à l'étude des ondes liquides". Bull. Inform. (COEC), **10** (1): 7–13. Paris, 1958.
Franco, A. S. "Marés em pequenas profundidades". Anais Hidrogr., **14**: 67–91. Rio de Janeiro, 1955.
Freeman, J. C., & Baer, L. "The method of wave derivatives". Trans. American Geophys. Union, **38** (4): 483–94. Washington, 1957.

Friedrichs, K. O. "The existence of solitary waves". Commun. Pure & Appl. Math., **7**: 517–50. New York, 1954.

Fuchs, R. A. "On the theory of irregular waves". Counc. on Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.

Gelci, R., Cazalé, H., & Vassal, J. "Prévision de la houle; la méthode des densités spectroangulaires". Bull. Inform. (COEC), **8**: 416–35. Paris, 1957.

Glukhovskii, B. K., & Vilenskii, Y. G. "A wave-meter for the open sea". Meteorol. i Gidrol., 1956 (12): 51. Leningrad, 1956.

Grinda, L. "Ondes de pression sous-marines et enregistrements séismographiques". Bull. Inst. Océanogr., **1104**. Monaco, 1957.

Harris, D. L. "Some problems involved in the study of storm surges". Rep. Nation. Hurricane Res. Proj., **4**. USA, 1956.

Hayami, S. "On the tidal mixing of sea water through narrow channels". Rec. Oceanogr. Works Japan, **3** (1): 49–55. Tokyo, 1957.

Heybrock, W. "Gletscherrückgang und Erhöhung des Meeresspiegels". Petermanns Geogr. Mitt., **101** (3): 184–93. Gotha, 1957.

Ichiye, T. "On the storm surges caused by the typhoon 5415 'Marie' I". Rec. Oceanogr. Works Japan, **3** (1): 26–35. Tokyo, 1957.

Ichiye, T. "On the storm surges caused by the typhoon 5415 'Marie' II". Rec. Oceanogr. Works Japan, **3** (1): 36–48. Tokyo, 1957.

Inglis, C. G. "The east coast storm surge and floods of 1953". Hydraulics Res., 1954: 6. London, 1955.

Kajiura, K. "A forced wave caused by atmospheric disturbances in deep water". Techn. Rep. Dept. Oceanogr. A & M College Texas, **133–1** (Ref. 56–26). Austin, 1956.

Krylov, Y. M. "On the connection between the steepness and growth of waves produced by wind". Meteorol. i Gidrol., 1957 (1): 26. Leningrad, 1957.

de Leonibus, P. S. "Climatological data on the generation and propagation of waves in the North Atlantic". Counc. Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.

Littmann, W. "On the existence of periodic waves near critical speed". Commun. Pure & Appl. Math., **10** (2). New York, 1957.

Longinov, V. V. "Some observations on the deformation of a wave in the coastal zone under natural conditions". Trudy Inst. Okeanol. Akad. Nauk SSSR, **21**: 47–106. Moscow, 1957.

Mandelbaum, H. "Wind influence on a rotary tidal current". Trans. American Geophys. Union, **38** (6): 867–78. Washington, 1957.

Merino, J., & Coronado, J. M. "Variaciónes periódicas del nivel del mar en Mexico". An. Inst. Geofis., **2**. Mexico, 1956.

Miskin, E. A., & Kemp, P. H. "Wave measurements by stereo photogrammetric methods". Dock & Harb. Auth., **37**: 335–37. London, 1957.

Nakano, M. "Atomic energy and the oscillation of sea level". Collect. Repr. Oceanogr. Lab. Meteorol. Res. Inst. Tokyo, **3**. Tokyo, 1956.

Neumann, J. "On the range of variation in sea level". J. Mar. Res., **15** (3): 204–11. New Haven, Conn., 1956.

Phillips, O. M. "On the generation of waves by turbulent wind". J. Fluid Mechan., **2** (5): 417–45. London, 1957.

Pierson, W. J., & Chang, S. S. L. "A wave spectrum analyzer". Counc. on Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.

Proudman, J. "Oscillations of tide and surge in an estuary of finite length". J. Fluid Mechan., **2** (4): 371. London, 1957.

Putz, R. R. "Measurement and analysis of ocean waves". Counc. on Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.

Rattray, M. "Propagation and dissipation of long internal waves". Trans. American Geophys. Union, **38** (4): 495–500. Washington, 1957.

Rattray, M. "On the offshore distribution of tide and tidal current". Trans. American Geophys. Union, **38** (5): 675–80. Washington, 1957.

Reid, R. O. "Modification of the quadratic bottom-stress law for turbulent channel flow in the presence of surface wind-stress". Techn. Rep. Dept. Oceanogr. A & M College Texas, **133–2** (Ref. 56–27). Austin, 1956.

Roumegoux, L. "Les marées de Normandie". Bull. Sect. Géogr., Comité Trav. Hist. Sci., **69**. Paris, 1957.

Saville, T. "Wave forecasting". Counc. Wave Res. & Soc. Naval Archit. & Mar. Engin., Proc. 1st Conf. on Ships & Waves, Hoboken, October, 1954. 1955.

Shebalin, O. D. "Turbulent viscosity in a shallow sea, due to waves". Doklady Akad. Nauk SSSR, **116** (4): 591. Moscow, 1957.

Shoulejkin, W. "Wind wave profile and its record by bottom wave-recorders". Doklady Akad. Nauk SSSR, **115** (5): 915. Moscow, 1957.

Silvester, R. "Practical application of Darbyshire's method of hindcasting ocean waves". Australian J. Appl. Sci., Ser. 2, **6** (3). Melbourne, 1955.

Snodgrass, F., & Munk, W. H. "Off-shore recording of ocean waves in the band of 1 to 100 cycles per kilosecond". Trans. American Geophys. Union, **38** (3): 407. Washington, 1957.

Stommel, H., & Redfield, A. G. "Memorandum on the proposed steric sea level measurements of the IGY program in oceanography". IUGG Chronicle, **2**: 62–64. Paris, 1957.

Unoki, S. "On the speed, travel time and direction of ocean waves due to tropical cyclones". J. Meteorol. Soc. Japan, **34** (6). Tokyo, 1956.

Unoki, S. "On the ocean waves due to tropical cyclones (2nd paper): distribution of waves viewed from geometric consideration and typhoon reconnaissance by aircraft". J. Meteorol. Soc. Japan, Ser. 2, **35** (2). Tokyo, 1957.

Unoki, S., & Nakano, M. "On the Cauchy-Poisson waves caused by the eruption of a submarine volcano, III". Pap. Meteorol. & Geophys., **4**: 139–50. Tokyo, 1953.

Vantroys, L. "La détermination des marées au-dessus des fonds océaniques". CR Acad. Sci., **245** (3). Paris, 1957.

Vantroys, L. "Note sur l'utilisation de la surface libre des mers dans les opérations de nivellement". Bull. Inform. (COEC), **10** (1): 14–18. Paris, 1958.

Wiegel, R. L., & Kukk, J. "Wave measurements along the California coast". Trans. American Geophys. Union, **38** (5): 667–74. Washington, 1957.

Yegorov, E. N. "On the stability of the contours of irregular coasts with a wave resultant normal to the coastline". Trudy Inst. Okeanol. Akad. Nauk SSSR, **21**: 107–17. Moscow, 1957.

2) h Ice

Bailey, W. B., & Lauzier, L. M. "Incidence of ice and icebergs in the entrances to the Gulf of St. Lawrence and along the south coast of Newfoundland". Atlantic Oceanogr. Group, St. Andrews, 1956.

Debenham, F. "The ice islands of the Arctic: a hypothesis". Geogr. Rev., **44**: 495–507. New York, 1954.

Felsenbaum, A. I. "On the tightening and loosening of ice fields in the Arctic basin". Doklady Akad. Nauk SSSR, **116** (2): 217. Moscow, 1957.

Goedecke, E. "Neuere Untersuchungen über die Vorbereitungs- und Abschmelzzeit des Eises in der Deutschen Bucht und westlichen Ostsee". Ann. Meteorol., **8** (3/4): 80–92. Hamburg, 1957.

Goedecke, E. "Das merkwürdige Verhalten der Eiswinter 1953/54 bis 1955/56". Seewart, **18**: 9–22. Hamburg, 1957.

Kolesnikov, A. G., & Belyaev, V. I. "On the calculation of the process of the crystallization of supercooled water by turbulent mixing". Izvest. Akad. Nauk SSSR, Ser. Geofiz., 1956 (11): 1322. Moscow, 1956.

Kryndin, A. N. "On the relation between the total amount of ice and the depth of ice in the Baltic". Meteorol. i Gidrol., 1957 (2): 19. Leningrad, 1957.

Sala, I. "Einige Messungen der Eisfestigkeit". Geophysica, **5** (3). Helsinki, 1957.

Schell, I. I. "Interrelations of Arctic ice with the atmosphere and the ocean in the North Atlantic – Arctic and adjacent areas". J. Meteorol., **13**: 46–58. Lancaster, Pa., 1955.

Uusitalo, S. "Beobachtungen mit Bezug auf das Meereseis". Geophysica, **5** (3). Helsinki, 1957.

Weeks, W. F., & Lee, O. S. "Observations on the growth of sea ice at Hopedale, Labrador". Trans. American Geophys. Union, **38** (3): 412. Washington, 1957.

2) i Coastal Oceanography and Limnology

Allen, F. H., & Grindley, J. "Radioactive tracers in the Thames estuary". Dock & Harb. Auth., **435**: 302–06. London, 1957.

Barlow, J. P. "Effect of wind on salinity distribution in an estuary". J. Mar. Res., **15** (3): 193–203. New Haven, Conn., 1956.

Burt, W. V., & Queen, J. "Tidal overmixing in estuaries". Science, **126** (3280): 973. Lancaster, Pa., 1957.

Debyser, J. "La sédimentation dans le bassin d'Arcachon". Bull. Centre Etud. et Rech. Sci. Biarritz, **1** (3): 405–18. Biarritz, 1957.

Gameson, A. L. H. "The Thames Estuary and its pollution. 3. Rate of solution of atmospheric oxygen". Challenger Soc., **3** (9): 32. London, 1957.

Gautier, Y. V. "Résultats de quatre nouveaux lancers de flotteurs dérivants devant le Delta du Rhône". Rec. Trav. Stat. Mar. Endoume, **22**: 65–70. Marseille, 1957.

Hatcher, J. R. "On the boundary between fresh water and salt water in an estuary". Bull. American Phys. Soc., **1**: 265–66. USA, 1956.

Hiyama, Y., *et al.* "State and behaviour of fission products in fresh-water, brackish-water and marine coastal systems in Japan, 1954 1955". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1027–65. Tokyo, 1956.

Kändler, R. "Die hydrologischen Verhältnisse in den Buchten und Förden der Ostküste Schleswig-Holsteins im Hinblick auf die Abwasserbelastung". Arb. Deutsche Fisch.-Verb., 1956 (7): 17. 1956.

Middleton, F. H., & Wen-Hsiung, Li. "An ultrasonic current meter for estuarine research". Inst. Coop. Res., Johns Hopkins Univ., Baltimore, 1954.

Moon, F. W., Breitschneider, C. L., & Hood, D. "A method for measuring eddy diffusion in coastal embayments". Publ. Inst. Mar. Sci., **4** (2): 14–21. Port Aransas, Texas, 1957.

Pickard, G. L., & Trites, R. W. "Fresh water transport determination from the heat budget with applications to British Columbia inlets". J. Fish. Res. Board Canada, **14** (4): 605–16. Ottawa, 1957.

Preddy, W. S. "The Thames Estuary and its pollution. 4. Prediction of conditions in the estuary". Challenger Soc., **3** (9): 32. London, 1957.

Proudman, J. "Oscillations of tide and surge in an estuary of finite length". J. Fluid Mechan., **2** (4): 371–82. London, 1957.

Reid, G. K. "Biologic and hydrographic adjustment in a disturbed Gulf Coast estuary". Limnol. & Oceanogr., **2** (3): 198–212. Baltimore, 1957.

Rivière, A. "Études littorales". Bull. Inform. (COEC), **8**: 436–54. Paris, 1957.

Saiz, F., Lopez-Benito, M., & Anadon, E. "Estudio hidrografico de la ria de Vigo". Invest. Pesqu., **8**: 29–87. Barcelona, 1957.

Slomianko, P. "Contribution to the analysis of the coastal movement of sands". Arch. Hydrotechn., **3**: 379–94. Warsaw, 1956.

Southgate, B. A. "The Thames Estuary and its pollution. 1. An outline of the problem". Challenger Soc., **3** (9): 31. London, 1957.

Takano, K. "A complementary note on the diffusion of the seaward river flow off the mouth". J. Oceanogr. Soc. Japan, **11** (4): 147. Tokyo, 1956.

Tabata, S., & Pickard, G. L. "The physical oceanography of Bute Inlet, British Columbia". J. Fish. Res. Board Canada, **14** (4): 487–520. Ottawa, 1957.

Vernhet, S. "Sur certains phénomènes morphologiques et hydrodynamiques observés sur la côte languedocienne". Bull. Inform. (COEC), **9**: 500–07. Paris, 1957.

Vollbrecht, K. "Über die Natur des Sedimentgleichgewichtes im Litoral". Geofis. Pura e Appl., **28**: 159–70. Milano, 1954.

Wheatland, A. B. "The Thames Estuary and its pollution. 2. Oxidation and reduction processes". Challenger Soc., **3** (9): 31. London, 1957.

Zenkovich, V. P. "On the origin of the off-shore bars and lagoons". Trudy Inst. Okeanol. Akad. Nauk SSSR, **21**: 3–39. Moscow, 1957.

3) Plankton

3) a General

Barham, E. G. "The cod-end sampler". Pubbl. Staz. Zool. Napoli, **30** (1): Note Techniche. Napoli, 1957.

Beklemishev, K. V. "On the spatial relationships between marine zoo- and phytoplankton". Trudy Inst. Okeanol., **20**: 253. Moscow, 1957.

Bogorov, B. G. "Standardization of marine plankton investigations". Trudy Inst. Okeanol. Akad. Nauk SSSR, **24**: 200–14. Moscow, 1957.

Brodsky, K. A., & Vinogradov, M. E. "On the distribution of plankton in the Indian sector of the Antarctic region. (According to data collected on the 1st voyage of the combined Antarctic Expedition of the USSR Academy of Sciences)". Doklady Akad. Nauk SSSR, **112** (5). Moscow, 1957.

Bsharah, L. "Plankton of the Florida current. V. Environmental conditions, standing crop, seasonal and diurnal changes at a station 40 miles east of Miami". Bull. Mar. Sci. Gulf & Caribbean, **7** (3): 201–51. Coral Gables, Fla., 1957.

Cachon, J. "Sur quelques techniques de pêches planctoniques pour études biologiques". Bull. Inst. Océanogr., **1103**. Monaco, 1957.

Chiba, T., *et al.* "Oceanographical and planktological studies of the tuna-fishing grounds in the middle part of the North Indian Ocean". J. Shimonoseki College Fish., **6** (3): 291–329. Shimoneseki City, 1957.

Comita, G. W., & Comita, J. J. "The internal distribution patterns of a calanoid copepod population, and a description of a modified Clarke-Bumpus plankton sampler". Limnol. & Oceanogr., **2** (4): 321–32. Baltimore, 1957.

Glover, R. S. "Recent changes in the North Sea herring fisheries. Appendix I. The environment: the evidence of the plankton". ICES, R. et P.-V., **143** (1): 22–24. Copenhague, 1957.

Griffith, R. E. "A portable apparatus for collecting horizontal plankton samples". Ecology, **38** (3): 538–40. Durham, N.C., 1957.

Herbst, H. V. "Der Fallschöpfer, ein Gerät zum quantitativen Zooplankton-Fang". Arch. Hydrobiol., **53** (4): 598–603. Stuttgart, 1957.

Ichiye, T. "On the relationship between the plankton distribution and hydrographic condition in the adjacent seas of Japan". Rec. Oceanogr. Works Japan, Spec. No. Oceanogr. Res. Proj. Japanese Nation. Commiss. UNESCO: 34–41. Tokyo, 1957.

Igarashi, S. "On the filtering-rate of plankton net". Bull. Fac. Fish. Hokkaido Univ., **8** (1): 48–50. Hakodate, 1957.

Lebedeva, M. N. "Quantitative distribution and biomass of microorganisms within the oxygen zone of the Black Sea". Doklady Akad. Nauk SSSR, **115** (1): 186. Moscow, 1957.

Légaré, J. E. H. "The qualitative and quantitative distribution of plankton in the Strait of Georgia in relation to certain oceanographic factors". J. Fish. Res. Board Canada, **14** (4): 521–52. Ottawa, 1957.

Matsue, Y., & Hirano, R. "Accumulation of radioactivity in plankton cultured or kept in water infusions of the 'Bikini ash'". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1099–104. Tokyo, 1956.

Motoda, S., Anraku, M., & Minoda, T. "Experiments on the performance of plankton samplings with net". Bull. Fac. Fish. Hokkaido Univ., **8** (1): 1–22. Hakodate, 1957.

Seymour, A. H., *et al.* "Survey of radioactivity in the sea and in pelagic marine life west of the Marshall Islands, September 1–20, 1956". US Atomic Energy Commiss., UWFL, Appl. Fish. Lab., **47**: 1–57. USA, 1957.

Sutcliffe, W. H. "An improved method for the determination of preserved plankton volumes". Limnol. & Oceanogr., **2** (3): 295–96. Baltimore, 1957.

3) b Zooplankton

Alvariño, A. "Estudio del zooplancton del Mediterráneo occidental. Campaña del 'Xauen', en el verano del 1954". Bol. Inst. Español Oceanogr., **81**. Madrid, 1957.

Alvariño, A. "Zooplancton del Atlántico Iberico. Campaña del 'Xauen' en el verano del 1954". Bol. Inst. Español Oceanogr., **82**. Madrid, 1957.

Anichini, C. "Ricerche di biologia marina nei mari circostanti la Sardegna". Bull. Inst. Océanogr., **1098**. Monaco, 1957.

Anichini, C., & Spedaletti, L. "Ricerche di biologia marina nei mari circostanti la Sardegna: II. Variazioni dello zooplancton nella pescata orizzontale a m. 1 di profondità nella parte occidentale del Golfo di Cagliari nei mesi di ottobre – novembre – dicembre 1956". Bull. Inst. Océanogr., **1101**. Monaco, 1957.

Björnberg, T. K. S., & Forneris, L. "Resultados cientificos do cruzeiro do 'Baependi' e do 'Vega' a Ilha de Trindade. Copelata I". Contr. Avulsas Inst. Oceanogr., Oceanogr. Biol., **1**. São Paulo, 1955.

Boden, B. P., & Brinton, E. "The euphausiid crustaceans *Thysanopoda aequalis* Hansen and *Thysanopoda subaequalis* Boden, their taxonomy and distribution in the Pacific". Limnol. & Oceanogr., **2** (4): 337–41. Baltimore, 1957.

Bogorov, V. G., & Vinogradov, M. E. "Basic characteristics of the distribution of zooplankton in the northwest part of the Pacific Ocean". Trudy Inst. Okeanol. Akad. Nauk SSSR, **18**: 113–23. Moscow, 1955.

Codreanu, R. "Sur quatre espèces nouvelles de microsporidies parasites de l'*Artemia salina* (L.) de Roumanie". Ann. Sci. Natur., Zool. et Biol. Anim., **19** (4): 561–72. Paris, 1957.

Dales, R. P. "Pelagic polychaetes from the Bay of Biscay". Ann. & Mag. Natur. Hist., Ser. 12, **10** (117): 661–64. London, 1957.

Edmondson, W. T. "Trophic relations of the zooplankton". Trans. American Miscroscop. Soc., **76** (3): 225–45. Columbus, Ohio, 1957.

Fisher, L. R., Kon, S. K., & Thompson, S. Y. "Vitamin A and carotenoids in certain invertebrates. VI. Crustacea: Penaeidea". J. Mar. Biol. Assoc., **36** (3): 501–07. Cambridge, 1957.

Fleminger, A. "New calanoid copepods of *Pontella* Dana and *Labidocera* Lubbock with notes on the distribution of the genera in the Gulf of Mexico". Tulane Stud. Zool., **5** (2). New Orleans, 1957.

Furnestin, M.-L. "Chaetognathes et zooplancton du secteur Atlantique Marocain". Rev. Trav. Inst. Pêches Marit., **21** (1 & 2). Paris, 1957.

Gauld, D. T. "Copulation in calanoid copepods". Nature, **180** (4584): 510. London, 1957.

Kiefer, F. "Freilebende Ruderfusskrebse (Crustacea Copepoda) aus einigen ostanatolischen Seen". Zool. Anzeig., **159** (1–2): 25–33. Leipzig, 1957.

Manuilova, E. F. "The relation of the variability of pelagic Cladocera to the development of bacteria in the water". Doklady Akad. Nauk SSSR, **103** (6): 1111–14. Moscow, 1955.

Petipa, P. S. "Observations on the behaviour of zooplankton during a solar eclipse". Doklady Akad. Nauk SSSR, **104** (2): 323–25. Moscow, 1955.

Ponomareva, L. A. "Zooplankton of the western part of the Kara Sea and the Bajdarazk Bayou". Trudy Inst. Okeanol., **20**: 228. Moscow, 1957.

Rae, K. M. "A relationship between wind, plankton distribution and haddock brood strength". Bull. Mar. Ecol., **4** (38): 247–69. Edinburgh, 1957.

Rees, C. B. "Continuous plankton records: the distribution of *Calanus finmarchicus* (Gunn.) in the North Sea and north-eastern Atlantic, 1946–1953". Bull. Mar. Ecol., **5** (37): 211–46. Edinburgh, 1957.

Russell, F. S. "On a new medusa, *Krampella dubia* n. g., n. sp." J. Mar. Biol. Assoc., **36** (3): 445–47. Cambridge, 1957.

Tattersall, O. S. "Report on a small collection of Mysidacea from the Sierra Leone estuary together with a survey of the genus *Rhopalopthalmus* Illig and a description of a new species of *Tenagomysis* from Lagos, Nigeria". Proc. Zool. Soc. London, **129** (1): 81–128. London, 1957.

Wald, G., & Brown, P. K. "The vitamin A of a euphausiid crustacean". J. Gen. Physiol., **40** (4): 627–34. Baltimore, 1957.

Woodhead, P. M. J., & Riley, J. D. "The separation of potential males and females in stage-V copepodites of *Calanus helgolandicus*". ICES, J. Cons., **23** (1): 47–50. Copenhague, 1957.

3) c Phytoplankton

Ballantine, D., & Abbott, B. C. "Toxic marine flagellates; their occurrence and physiological effects on animals". J. Gen. Microbiol., **16**: 274–81. London, 1957.

Baslavskaya, S. S., & Kulikova, R. F. "The photometric method for measuring the growth of algal cultures". Byull. Moskovsk. Obshch. Ispyt. Prirody, **61** (6). USSR, 1956.

Bently, J. A. "Effect of plant hormones on marine diatoms in culture". Challenger Soc., **3** (9): 27. London, 1957.

Davis, P. S. "A method for the determination of chlorophyll in sea-water". CSIRO, Rep. Div. Fish. & Oceanogr., **7**. Sydney, 1957.

Desikachary, T. V. "Electron microscope studies on diatoms". J. Roy. Miscroscop. Soc., **76** (1 & 2): 9–36. London, 1957.

Geitler, L. "Die sexuelle Fortpflanzung der pennaten Diatomeen". Biol. Rev., **32** (3): 261–95. Cambridge, 1957.

Hart, T. J. "Notes on practical methods for the study of marine diatoms". J. Mar. Biol. Assoc., **36** (3): 593–97. Cambridge, 1957.

Hollande, A., & Enjumet, M. "Sur une invasion des eaux du port d'Alger par *Chattonella subsalsa* (= *Hornellia marina* Sub.) Biecheler. Remarques sur la toxicité de cette Chloromonadine". Trav. Stat. Aquicult. et Pêche Castiglione, **8**: 271–79. Castiglione, 1957.

Holmes, R. W. "The annual cycle of phytoplankton in the Labrador Sea, 1950–51". Bull. Bingham Oceanogr. Collect., **16** (1): 3–74. New Haven, Conn., 1956.

Jørgensen, E. G. "Diatom periodicity and silicon assimilation. Experimental and ecological investigations". Dansk Bot. Ark., **18** (1): 1–54. København, 1957.

Kolbe, R. W. "Zur Deutung und Auswertung elektronenmikroskopischer Aufnahmen in der Diatomeenkunde". Bot. Notiser, **109** (3): 368–73. Lund, 1956.

Lasker, R., & Holmes, R. W. "Variability in retention of marine phytoplankton by membrane filters". Nature, **180** (4597): 1295. London, 1957.

Lewin, J. C. "Silicon metabolism in diatoms. IV. Growth and frustule formation in *Navicula pelliculosa*". Canadian J. Microbiol., **3**: 427–33. Ottawa, 1957.

Margalef, R. "Fitoplancton de las costas de Blanes (Gerona) de agosto de 1952 a junio de 1956". Invest. Pesqu., **8**: 89–95. Barcelona, 1957.

Margalef, R. "Variación local e interanual en la secuencia de las poblaciones de fitoplancton de red en las aguas superficiales de la costa mediterránea española". Invest. Pesqu., **9**: 65–95. Barcelona, 1957.

Matsue, Y., & Hirano, R. "On the relation between carbon dioxide supply and phytoplankton growth". Japanese J. Limnol., **17**: 133–40. Tokyo, 1955.

McCleod, G. C. "The effect of circularly polarized light on the photosynthesis and chlorophyll *a* production of certain marine algae". Limnol. & Oceanogr., **2** (4): 360–62. Baltimore, 1957.

Parke, M., & Ballantine, D. "A new marine dinoflagellate: *Exuviaella mariaelebouriae* n. sp." J. Mar. Biol. Assoc., **36** (3): 643–50. Cambridge, 1957.

Raymont, J. E. G. "Sea plants for food?" New Scientist, **2** (35): 10–11. London, 1957.

Riley, G. A. "Phytoplankton of the North Central Sargasso Sea, 1950–52". Limnol. & Oceanogr., **2** (3): 252–70. Baltimore, 1957.

Ryther, J. H., & Yentsch, C. S. "The estimation of phytoplankton production in the ocean from chlorophyll and light data". Limnol. & Oceanogr., **2** (3): 281–86. Baltimore, 1957.

Smayda, T. J. "Phytoplankton studies in Lower Narrangansett Bay". Limnol. & Oceanogr., **2** (4): 342–59. Baltimore, 1957.

Sorokin, Y. I., & Kozlianinov, M. V. "Determination of the relation between phytoplankton photosynthesis and the illumination of water in the Sea of Japan and in the Pacific". Doklady Akad. Nauk SSSR, **116** (5): 863. Moscow, 1957.

Sousa e Silva, E. "Dinoflagelados do plâncton marinho de Angola". Trab. Miss. Biol. Marít., 1955 (15): 107–91. Lisboa, 1957.

von Stosch, H. A. "Entwicklungsgeschichtliche Untersuchungen an zentrischen Diatomeen. II". Arch. Mikrobiol., **25** (4): 327–65. Berlin, 1956.

Talling, J. F. "The phytoplankton population as a compound photosynthetic system". New Phytol., **56** (2): 133–49. Oxford, 1957.

Talling, J. F. "Diurnal changes of stratification and photosynthesis in some tropical African waters". Proc. Roy. Soc., Ser. B, **147** (926): 57–83. London, 1957.

Verduin, J. "Daytime variations in phytoplankton photosynthesis". Limnol. & Oceanogr., **2** (4): 333–36. Baltimore, 1957.

3) d Nanoplankton

Gaarder, K. R., & Markali, J. "On the coccolithophorid *Crystallolithus hyalinus* n. gen. n. sp." Nytt Mag. Bot., **5**: 1–5. Oslo, 1957.

Kitching, J. A. "Effects of high hydrostatic pressures on the activity of flagellates and ciliates". J. Exper. Biol., **34** (4): 494–510. Cambridge, 1957.

Kufferath, J. "Tentative d'estimation gravimétrique de l'ultraplancton dans l'eau de la Méditerranée". Bull. Inst. Océanogr., **1088**. Monaco, 1957.

Kufferath, H. "Examen microscopic d'ultraplancton recueilli au large de Monaco". Bull. Inst. Océanogr., **1089**. Monaco, 1957.

Markali, J., & Paasche, E. "On two species of *Umbellosphaera*, a new marine coccolithophorid genus". Nytt Mag. Bot., **4**: 95–100. Oslo, 1955.

3) e Productivity

Guseva, K. A. "Modification by K. A. Guseva of the hydrobiological productivity". Freshwater Life of the USSR, **4** (1): 149–51. Moscow, 1956.
Holmes, R. W., Schaefer, M. B., & Shimada, B. M. "Primary production, chlorophyll, and zooplankton volumes in the tropical eastern Pacific Ocean". Bull. Inter-American Trop. Tuna Commiss., **2** (4). La Jolla, Cal., 1957.
Jitts, H. R. "The ^{14}C method for measuring CO_2 uptake in marine productivity studies". CSIRO, Rep. Div. Fish. & Oceanogr., **8**. Sydney, 1957.
Nielsen, E. S. "The chlorophyll content and the light utilization in communities of plankton algae and terrestrial higher plants". Physiol. Plantarum, **10** (5): 1009–21. Copenhagen, 1957.
Oliver, J. H. "Production of carbon in the sea". Nature, **180** (4586): 617. London, 1957.

4) Benthos

4) a General

Danilshenko, O. P. "Marking oligochaetes (*Enchytraeus*) with radio-active strontium". Rybn. Khoz., 1957 (6): 78–80. Moscow, 1957.
Ercegovic, A. "Principe et essai d'un classement des étages benthiques". Rec. Trav. Stat. Mar. Endoume, **22**: 17–21. Marseille, 1957.
Gautier, Y. V. "Recherches sur les biocoenoses benthiques des côtes de Camargue et du Golfe de Fos". Rec. Trav. Stat. Mar. Endoume, **22**: 55–64. Marseille, 1957.
Klawe, W. L., & Dickie, L. M. "Biology of the bloodworm, *Glycera dibranchiata* Ehlers, and its relation to the bloodworm fishery of the Maritime Provinces". Bull. Fish. Res. Board Canada, **115**. Ottawa, 1957.
Kohn, A. J., & Helfrich, P. "Primary organic productivity of a Hawaiian coral reef". Limnol. & Oceanogr., **2** (3): 241–51. Baltimore, 1957.
Pérès, J. M. "Essai de classement des communautés benthiques marines du Globe". Rec. Trav. Stat. Mar. Endoume, **22**: 23–54. Marseille, 1957.
Warburton, F. E. "Removing intact bivalves from their shells". Pubbl. Staz. Zool. Napoli, **30** (1): Note Techniche. Napoli, 1957.

4) b Fauna, Systematics and Development

Ax, P. "Studien über psammobionte Turbellaria Macrostomida IV. *Myozona stylifera* nov. spec." Zool. Anz., **157** (11–12): 251–60. Leipzig, 1956.
Birstein, J. A. "Certain peculiarities of the ultra-abyssal fauna at the example of the genus *Storthyngura* (Crustacea Isopoda Assellota)". Zool. Zhurn., **36** (7): 961. Moscow, 1957.
Björnberg, T. K. S. "Sôbre quatro tornárias do Atlantico e do Mediterraneo". Bol. Inst. Oceanogr., **6** (1 & 2): 197–207. São Paulo, 1955.
Bone, Q. "The problem of the 'Amphioxides' larva". Nature, **180** (4600): 1462–64. London 1957.
Boycott, B. B. "An octopus lays eggs at London Zoo". New Scientist, **2** (47): 12–13. London, 1957.
Brattström, H. "*Branchiocerianthus norvegicus* n. sp. from the Hardangerfjord, Western Norway". Univ. Bergen, Årbok, 1957 (6). Bergen, 1957.
Domingo, C. M. "Sur l'existence du *Colpomenia peregrina* (Sauv.) Hamel dans la Méditerranée". Vie et Milieu, **8** (1): 92–98. Paris, 1957.
Eales, N. B. "Revision of the species of *Aplysia* of the Musée National d'Histoire Naturelle (Malacologie), Paris". Bull. Mus. Nation. Hist. Natur., **29** (3): 246–55. Paris, 1957.
Gabe, M., & Prenant, M. "Recherches sur la gaine radulaire des mollusques. VI. L'appareil radulaire de quelques céphalopodes". Ann. Sci. Natur., Zool. et Biol. Anim., **19** (4): 587–602. Paris, 1957.
Gordan, J. "A bibliography of the order Mysidacea". Bull. American Mus. Natur. Hist., **112** (4). New York, 1957.
Hartman, O. "Orbiniidae, Apistobranchidae, Paraonidae and Longosomidae". Allan Hancock Pacific Exped., **15** (3). Los Angeles, 1957.
Hartmann-Schröder, G. "Polychaeten-Studien I". Zool. Anz., **157** (5–6): 87–91. Leipzig, 1956.
Hartmann-Schröder, G. "Polychaeten-Studien II". Zool. Anz., **157** (5–6): 92–101. Leipzig, 1956.

Humes, A. G. "Deux copépodes harpacticoides nouveaux du genre *Tisbe*, parasites des holothuries de la Méditerranée". Vie et Milieu, **8** (1): 9–22. Paris, 1957.

Iwai, E. "Descriptions on unidentified species of dibranchiate cephalopods. I. An oegopsiden squid belonging to the genus *Architeuthis*". Sci. Rep. Whales Res. Inst., **11**: 139–51. Tokyo, 1956.

Iwai, E. "A Cranchiidae squid of the genus *Taonius*". Sci. Rep. Whales Res. Inst., **11**: 153–61. Tokyo, 1956.

Jägersten, G. "On the larva of *Siboglinum*. With some remarks on the nutrition problem of the Pogonophora". Zool. Bidrag Uppsala, **32**: 67–79. Uppsala & Stockholm, 1957.

Johansson, J. "On the anatomy of *Tympanotonus fuscatus* (L.) including a survey of the open pallial oviducts of the Cerithiacea". Atlantide Rep., **4**: 149–66. Copenhagen, 1956.

Johansson, J. "Notes on the littorinacean and stenoglossan genital organs, and a comparison with the Rissoacea". Zool. Bidrag Uppsala, **32**: 81–91. Uppsala & Stockholm, 1957.

Kaufman, Z. S. "The regeneration of the scyphistoma in the scyphomedusa, *Cyanea capillata*, as dependent on its development stage". Doklady Akad. Nauk SSSR, **114** (6): 1317. Moscow, 1957.

Kiefer, F. "Freilebende Ruderfusskrebse (Crustacea copepoda) aus türkischen Binnengewässern. II. Cyclopida und Harpacticoida". Hidrobiol., Ser. B, **2** (4): 108–32. Istanbul, 1955.

Lebouche, A.-P. "Observations sur l'écologie et sur la composition glucidique de *Caulasanthus ustulatus*". Bull. Centre Étud. et Rech. Sci. Biarritz, **1** (3): 397–99. Biarritz, 1957.

Lutaud, G. "Le développement du bourgeon chez *Membranipora membranacea* (Linné), Bryozoaire Chilostome". Arch. Zool. Expér. et Gén., Not. et Rev., **94** (3): 148–61. Paris, 1957.

Papi, F. "Sopra un nuovo Turbellario arcooforo di particolare significato filetico e sulla posizione della fam. Hofsteniidae nel sistema dei Turbellari". Pubbl. Staz. Zool. Napoli, **30** (1): 132–48. Napoli, 1957.

Papi, F. "Tre nuovi Gastrotrichi mediterranei". Pubbl. Staz. Zool. Napoli, **30** (1): 176–83. Napoli, 1957.

Pettibone, M. H. "Endoparasitic polychaetous annelids of the family Arabellidae with descriptions of new species". Biol. Bull., **113** (1): 170–87. Lancaster, Pa., 1957.

Purchon, R. D. "The stomach in the Filibranchia and Pseudolamellibranchia". Proc. Zool. Soc. London, **129** (1): 27–59. London, 1957.

Rees, W. J. "Status of *Moerisia lyonsi* Boulenger and related hydroids". Nature, **180** (4583): 445. London, 1957.

Romanovsky, A. "Über die Identität der Arten *Argulus japonicus* Thiele und *Argulus pellucidus* Wagler". Zool. Anz., **157** (11–12): 264–65. Leipzig, 1956.

Stock, J. H. "Some notes on the genus *Macrochiron* Brady, 1872 (Copepoda, Cyclopoida)". Ann. & Mag. Natur. Hist., **10** (113): 378–82. London, 1957.

Stott, F. C. "Observations on the food canal and associated structures in the *Holothuria forskali* Delle Chiaje". Proc. Zool. Soc. London, **129** (1): 129–36. London, 1957.

Sutton, M. F. "The feeding mechanism, functional morphology and histology of the alimentary canal of *Terebella lapidaria* L. (Polychaeta)". Proc. Zool. Soc. London, **129** (4): 487–523. London, 1957.

Trueman, E. R. "Mucous gland cells of the outer mantle epithelium of *Arca noae*". Nature, **180** (4600): 1492. London, 1957.

Ubisch, L. "Doppelbildungen bei Seeigeln (*Psammechinus microtuberculatus*, *Paracentrotus lividus*)". Zool. Anz., **159** (1–2): 1–12. Leipzig, 1957.

Vernet-Cornubert, G. "Existence de caractères sexuels périodiques chez certains Décapodes Reptantia: *Dromia vulgaris* (Fabricius), *Pilumnis hirtellus* (Linné)". Bull. Inst. Océanogr., **1109**. Monaco, 1957.

Vevers, H. G., & Millott, N. "Carotenoid pigments in the integuments of the starfish *Marthasterias glacialis* (L.)". Proc. Zool. Soc. London, **129** (1): 75–80. London, 1957.

Wells, G. P. "Variation in *Arenicola marina* (L.) and the status of *Arenicola glacialis* Murdoch (Polychaeta)". Proc. Zool. Soc. London, **129** (3): 397–419. London, 1957.

4) c Fauna, Distribution and Ecology

Aleem, A. A. "Succession of marine fouling organisms on test panels immersed in deep-water at La Jolla, California". Hydrobiologia, **11** (1): 40–58. The Hague, 1957.

Amar, R. "Isopodes psammiques du Golfe de Marseille. I. Parasellidae du sable à *Amphioxus*". Rec. Trav. Stat. Mar. Endoume, **22**: 75–82. Marseille, 1957.
Baptist, J. O., Smith, O. R., & Ropes, J. W. "Migrations of the horseshoe crab *Limulus polyphemus* in Plum Island Sound, Mass." US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **220**. Washington, 1957.
Barnes, H. "The northern limits of *Balanus balanoides* (L.)". Oikos, **8** (1): 1–15. Copenhagen, 1957.
Beard, D. M. "Occurrence of *Elminius modestus* Darwin in Ireland". Nature, **180** (4595): 1145. London, 1957.
Berkeley, E., & Berkeley, C. "A new species and two new records of Polychaeta from eastern Canada". Canadian J. Zool., **34**: 267–71. Ottawa, 1956.
Bishop, M. W. H., *et al.* "Sur l'écologie des cirripèdes de la côte atlantique française". Bull. Inst. Océanogr., **1099**. Monaco, 1957.
Burton, M. "The sponges of West Africa". Atlantide Rep., **4**: 111–47. Copenhagen, 1956.
Cherbonnier, G. "Une ophiure nouvelle de Méditerranée: *Amphiura apicula* nov. sp." Vie et Milieu, **8** (2): 200–04. Paris, 1957.
Coe, W. R. "Fluctuations in populations of littoral marine invertebrates". J. Mar. Res., **15** (3): 212–32. New Haven, Conn., 1956.
Cognetti, G. "I Sillidi del Golfo di Napoli". Pubbl. Staz. Zool. Napoli, **30** (1): 1–100. Napoli, 1957.
Crowell, S. "*Eugymnanthea*, a commensal hydroid living in pelecypods". Pubbl. Staz. Zool. Napoli, **30** (1): 162–67. Napoli, 1957.
Dahl, E. "The distribution of deep sea Crustacea". Internat. Union Biol. Sci., Ser. B, **16**: 43–48. Naples, 1954.
Daniel, A. "The primary film as a factor in settlement of marine foulers". J. Madras Univ., **25B** (2): 189–200. Madras, 1955.
Delye, G. "Crustacés décapodes récoltés au cours de la croisière du Comité Local d'Océanographie et d'études des côtes d'Algérie aux îles Habibas". Bull. Inst. Océanogr., **1093**. Monaco, 1957.
Dieuzeide, R., & Roland, J. "Opérations de draguages et de chalutages effectuées au large des côtes Algériennes". Trav. Stat. Aquicult. et Pêche Castiglione, **8**: 11–27. Castiglione, 1957.
Ekman, S. "Betrachtungen über die Fauna der abyssalen Ozeanböden". Internat. Union Biol. Sci., Ser. B, **16**: 5–11. Naples, 1954.
Fage, L. "Remarques sur les conditions de vie de la faune benthique abyssale". Internat. Union Biol. Sci., Ser. B, **16**: 12–19. Naples, 1954.
Fage, L. "Remarques sur les pycnogonides abyssaux". Internat. Union Biol. Sci., Ser. B, **16**: 49–56. Naples, 1954.
Filatova, Z. A. "General aspect of the marine bivalves fauna of the northern seas of the U.S.S.R." Trudy Inst. Okeanol., **20**: 3. Moscow, 1957.
Freeman, R. F. H. "*Paravortex scrobiculariae* (Graff) in Great Britain". Nature, **180** (4596): 1213–14. London, 1957.
Gislen, T. "On the bathymetric distribution of the deep sea crinoids". Internat. Union Biol. Sci., Ser. B, **16**: 38–39. Naples, 1954.
Gontcharoff, M. "Sur l'existence de *Lineus ruber* en Méditerranée". Rec. Trav. Stat. Mar. Endoume, **22**: 71–74. Marseille, 1957.
Hamond, R. "Notes on the Hydrozoa of the Norfolk coast". Linnean Soc. London, **43** (291): 294–324. London, 1957.
Holmquist, C. "On aberrant specimens of *Praunus flexuosus* and some other opossum shrimps". Acta Borealia, A, Scientia, **13**. Tromsø, 1957.
Jones, N. S. "Cumacea from the west coast of Africa". Atlantide Rep., **4**: 183–212. Copenhagen, 1956.
Kinne, O. "Comparative biology of marine and brackish water animals". Année Biol., **33**: 87–92. Paris, 1957.
Kirkegaard, J. B. "The zoogeography of the abyssal polychaetes". Internat. Union Biol. Sci., Ser. B, **16**: 40–42. Naples, 1954.
Kisch, B. S. "*Balanus tulipiformis* Ellis on the Atlantic coast of France and an unusual situation for *B. amphitrite* Darwin". Nature, **181** (4603): 206. London, 1958.
Knudsen, J. "Marine prosobranchs of tropical West Africa (Stenoglossa)". Atlantide Rep., **4**: 7–110. Copenhagen, 1956.
MacDonald, R. "The Crustacea, Decapoda, of Belfast Loch". Ann. & Mag. Natur. Hist., Ser. 12, **10** (117): 656–60. London, 1957.

MADSEN, F. J. "Some general remarks on the distribution of the echinoderm fauna of the deep-sea". Internat. Union Biol. Sci., Ser. B, **16**: 30–37. Naples, 1954.

MOLINIER, R. "Aperçu bionomique sur les peuplements marins littoraux des côtes rocheuses méditerranéennes de l'Espagne". Trav. Stat. Aquicult. et Pêche Castiglione, **8**: 251–68. Castiglione, 1957.

NAGABUSHANAM, A. K. "*Sacculina gonoplaxae* Guerin-Ganivet, 1911, a rhizocephalan parasite new to British waters". Nature, **181** (4601): 57. London, 1958.

NAYLOR, E. "*Brachynotus sexdentatus* (Risso), a grapsoid crab new to Britain". Ann. & Mag. Natur. Hist., **10** (115): 520–23. London, 1957.

NAYLOR, E. "The occurrence of *Idotea metallica* Bosc in British waters". J. Mar. Biol. Assoc., **36** (3): 599–602. Cambridge, 1957.

NAYLOR, E. "Introduction of a grapsoid crab, *Brachynotus sexdentatus* (Risso), into British waters". Nature, **180** (4586): 616. London, 1957.

NAYLOR, E. "Immigrant marine animals in Great Britain". New Scientist, **2** (50): 21–23. London, 1957.

PAES-DA FRANCA, M. L. "Contribuição para o conhecimento da fauna malacológica de Angola – Gasterópodes Testáceos". Trab. Miss. Biol. Marit., 1955 (13): 47–85. Lisboa, 1957.

PAES-DA FRANCA, M. L. "Contribuição para o conhecimento da fauna malacológica de Angola – Moluscos bivalves". Trab. Miss. Biol. Marit., 1955 (14): 87–106. Lisboa, 1957.

PARKER, R. H., & CURRAY, J. R. "Fauna and bathymetry of banks on continental shelf northwest Gulf of Mexico". Bull. American Assoc. Petrol. Geol., **40** (10): 2428–39. Tulsa, Okl., 1956.

REID, G. K. "Biologic and hydrographic adjustment in a disturbed Gulf Coast estuary". Limnol. & Oceanogr., **2** (3): 198–212. Baltimore, 1957.

SORDI, M., & MAJIDI, P. "Osservazioni sui Nudibranchi e gli Ascoglossi (Gasteropodi Opistobranchi) del litorale livornese". Boll. Pesca, Piscicolt. e Idrobiol., **11** (2): 235–45. Roma, 1956.

SPÄRCK, R. "Origin and distribution of the deep sea bottom fauna. Summary of the colloquium". Internat. Union Biol. Sci., Ser. B, **16**: 89–90. Naples, 1954.

SQUIRES, H. J. "Decapod crustacea of the 'Calanus' expeditions in Ungava Bay, 1947 to 1950. 'Calanus' series No. 11". Canadian J. Zool., **35**: 463–94. Ottawa, 1957.

SQUIRES, H. J. "Squid, *Illex illecebrosus* (LeSueur), in the Newfoundland fishing area". J. Fish. Res. Board Canada, **14** (5): 693–728. Ottawa, 1957.

SUAU, P., & VIVES, F. "Sobre la presencia de *Gastrosaccus sanctus* (Van Beneden) en la desembocadura del rio Ebro". Invest. Pesqu., **8**: 121–26. Barcelona, 1957.

USHAKOV, P. V. "On the Polychaeta-fauna of Arctic and Antarctic". Zool. Zhurn., **36** (11): 1647. Moscow, 1957.

VINOGRADOVA, N. G. "Features of distribution of deep water bottom fauna in the ocean". Priroda, 1957 (6): 93–96. Moscow, 1957.

WEBB, J. E. "Cephalochordata of the coast of tropical West Africa". Atlantide Rep., **4**: 167–82. Copenhagen, 1956.

ZENKEWITCH, L. A. "Erforschungen der Tiefseefauna im nordwestlichen Teil des Stillen Ozeans". Internat. Union Biol. Sci., Ser. B, **16**: 72–85. Naples, 1954.

4) d Fauna, Physiology and Behaviour

ALLEN, M. J. "The breeding of polychaetous annelids near Parguera, Puerto Rico". Biol. Bull., **113** (1): 49–57. Lancaster, Pa., 1957.

BARNES, H. "The spring diatom increase and the 'spawning' of the common barnacle *Balanus balanoides*". Année Biol., **33**: 67–85. Paris, 1957.

BARNES, H., & BARNES, M. "Resistance to desiccation in intertidal barnacles". Science, **126** (3269): 358. Lancaster, Pa., 1957.

BLOWER, J. G. "Feeding habits of a marine centipede". Nature, **180** (4585): 560. London, 1957.

DE BRUIN, G. H. P., & CRISP, D. J. "The influence of pigment migration on vision of higher crustacea". J. Exper. Biol., **34** (4): 447–62. Cambridge, 1957.

BURDON-JONES, C., & CHARLES, G. H. "Light reactions of littoral gastropods". Nature, **181** (4602): 129–30. London, 1958.

CARPENTER, J. H., & CARGO, D. G. "Oxygen requirement and mortality of the blue crab in the Chesapeake Bay". Techn. Rep. Chesapeake Bay Inst., **13**. Baltimore, 1957.

Christensen, A. M. "The feeding behaviour of the seastar *Evasterias troschellii* Stimpson". Limnol. & Oceanogr., **2** (3): 180–97. Baltimore, 1957.

Clark, W. C. "Escape responses of herbivorous gastropods when stimulated by carnivorous gastropods". Nature, **181** (4602): 137. London, 1958.

Corner, E. D. S. "The modes of action of toxic agents. II. Factors influencing the toxicities of mercury compounds to certain crustacea". J. Mar. Biol. Assoc., **36** (3): 459–72. Cambridge, 1957.

Costlow, J. D., & Bookhout, C. G. "Body growth versus shell growth in *Balanus improvisus*". Biol. Bull., **113** (2): 224–32. Lancaster, Pa., 1957.

Crane, J. "Basic patterns of display in fiddler crabs (Ocypodidae, genus *Uca*)". Zoologica, **42** (2): 69–82. New York, 1957.

Creac'h, P. V. "Variations physiologiques du phosphore total de la coquille de *Gryphaea angulata* Lmk." Rev. Trav. Inst. Pêches Marit., **21** (3): 415–30. Paris, 1957.

Crowell, S., & Wyttenbach, C. "Factors affecting terminal growth in the hydroid *Campanularia*". Biol. Bull., **113** (2): 233–44. Lancaster, Pa., 1957.

Daniel, A. "Illumination and its effect on the settlement of barnacle cyprids". Proc. Zool. Soc. London, **129** (3): 305–49. London, 1957.

Démeusy, N. "Respiratory metabolism of the fiddler crab *Uca pugilator* from two different latitudinal populations". Biol. Bull., **113** (2): 245–53. Lancaster, Pa., 1957.

Durchon, M., & Frézal, J. "A comparative study of the neurosecretory function in nereidian worms at genital maturity". CR Acad. Sci., **241**: 445–47. Paris, 1955.

Ebbecke, U. "Reflexuntersuchungen an Coelenteraten". Pubbl. Staz. Zool. Napoli, **30** (1): 149–61. Napoli, 1957.

Fingerman, M. "Endocrine control of the red and white chromatophores of the dwarf crawfish, *Cambarellus shufeldti*". Tulane Stud. Zool., 5 (6): 137–48. New Orleans, La., 1957.

Fingerman, M., & Lowe, M. E. "Hormones controlling the chromatophores of the dwarf crawfish, *Cambarellus shufeldti*: their secretion, stability, and separation by filter paper electrophoresis". Tulane Stud. Zool., **5** (7): 149–71. New Orleans, La., 1957.

Fisher, L. R., Kon, S. K., & Place, P. A. "Vitamin A isomers in some eucaridan Crustacea". Proc. Roy. Soc., Ser. B, **147** (927): 200–17. London, 1957.

Fisher, L. R., Kon, S. K., & Thompson, S. Y. "Vitamin A and carotenoids in certain invertebrates. VI. Crustacea: Penaeidea". J. Mar. Biol. Assoc., **36** (3): 501–07. Cambridge, 1957.

Freeman, R. F. H., & Rigler, F. H. "The responses of *Scrobicularia plana* (da Costa) to osmotic pressure changes". J. Mar. Biol. Assoc., **36** (3): 553–67. Cambridge, 1957.

George, J. C., & Patel, B. S. "The seasonal variation in the fat content of the liver and gonads in a marine and fresh water decapod". J. Anim. Morphol. & Physiol., **3** (1): 49–55. Bombay, 1956.

Gong, J. K., Shipman, W. H., Weiss, H. V., & Cohn, S. H. "Uptake of fission products and neutron induced radionuclides by the clam". Proc. Soc. Exper. Biol. & Med., **95** (3): 451–54. New York, 1957.

Green, J. "The feeding mechanism of *Mesidotea entomon* (Linn.) (Crustacea: Isopoda)". Proc. Zool. Soc. London, **129** (2): 245–54. London, 1957.

Hancock, D. A. "The feeding behaviour of the sea urchin *Psammechinus miliaris* (Gmelin) in the laboratory". Proc. Zool. Soc. London, **129** (2): 255–91. London, 1957.

Johnson, M. W. "The copepod *Choniosphaera cancrorum* parasitizing a new host, the green crab *Carcinides maenas*". J. Parasitol., **43** (4): 470–73. Lancaster, Pa., 1957.

Jørgensen, C. B., & Dales, R. P. "The regulation of volume and osmotic regulation in some nereid polychaetes". Physiol. Comp. et Oecol., **4** (4): 357–74. Amsterdam, 1957.

Labat, R. "Observations sur le cycle annuel et la sexualité de *Paramysis nouveli* et *Paramysis bacescoi* (Crustacés Mysidacés) dans la région de Roscoff". Arch. Zool. Expér. et Gén., Not. et Rev., **94** (3): 162–73. Paris, 1957.

Lubet, P. "The neurosecretory cycle in *Chlamys varia* L. and *Mytilus edulis* L." CR Acad. Sci., **241**: 119–21. Paris, 1955.

Mathias, A. P., Ross, D. M., & Schachter, M. "Identification and distribution of 5-hydroxtryptamine in a sea anemone". Nature, **180** (4587): 658. London, 1957.

Messina, L. "Prime osservazioni sulla natura chimica del liquido perivisceral di *Arbacia lixula*". Pubbl. Staz. Zool. Napoli, **30** (1): 127–31. Napoli, 1957.

Moulton, J. M. "Sound production in the spiny lobster, *Panulirus argus* (Latreille)". Biol. Bull., **113** (2): 286–95. Lancaster, Pa., 1957.

Needham, A. E. "Factors affecting nitrogen-excretion in *Carcinides maenas* (Pennant)". Physiol. Comp. et Oecol., **4** (3): 209–39. Amsterdam, 1957.
Nicol, J. A. C. "Spectral composition of the light of polynoid worms". J. Mar. Biol. Assoc., **36** (3): 529–38. Cambridge, 1957.
Nicol, J. A. C. "Spectral composition of the light of *Chaetopterus*". J. Mar. Biol. Assoc., **36** (3): 629–42. Cambridge, 1957.
North, W. J. "Sensitivity to light in the sea anemone *Metridium senile* (L.). II. Studies of reaction time variability and the effects of changes in light intensity and temperature". J. Gen. Physiol., **40** (5): 715–33. Baltimore, 1957.
Phillips, J. H., & Abbott, D. P. "Isolation and assay of the nematocyst toxin of *Metridium senile fimbriatum*". Biol. Bull., **113** (2): 296–301. Lancaster, Pa., 1957.
Plessis, J. "Observation sur la reproduction de *Phyllodoce mucosa* Oerstedt". Bull. Mus. Nation. Hist. Natur., **29** (4): 340–44. Paris, 1957.
Roberts, J. L. "Thermal acclimation of metabolism in the crab, *Pachygrapsus crassipes* Randall. I. The influence of body size, starvation, and molting". Physiol. Zool., **30** (3): 232–41. Chicago, 1957.
Roberts, J. L. "Thermal acclimation of metabolism in the crab, *Pachygrapsus crassipes* Randall. II. Mechanisms and the influence of season and latitude". Physiol. Zool., **30** (3): 241–54. Chicago, 1957.
Robertson, J. D. "Osmotic and ionic regulation in aquatic invertebrates". Recent Advances in Invertebrate Physiol., Symposium 1955: 229–46. Oregon, 1957.
Ross, D. M. "Responses of *Cerianthus* to stimulation". Nature, **180** (4598): 1368. London, 1957.
Snodgrass, R. E. "Crustacean metamorphoses". Smithsonian Misc. Collect., **131** (10): 1–78. Washington, 1956.
Tashian, R. E. "Geographic variation in the respiratory metabolism and temperature coefficient in tropical and temperate forms of the fiddler crab, *Uca pugnax*". Zoologica, **40** (6): 39–47. New York, 1955.
Thompson, T. G., & Chow, T. J. "Strontium-calcium atom ratio in carbonate-secreting marine organisms". Univ. Washington Publ. Oceanogr., **184**: 20–39. Washington, 1955.
Vernet-Cornubert, G. "Evolution du régénerat de la pince de *Pisa tetraodon* (Pennant) en fonction de la maturité sexuelle". Bull. Inst. Océanogr., **1097**. Monaco, 1957.
Voss, G. L. "Observations on abnormal growth of the arms and tentacles in the squid genus *Rossia*". Quart. J. Florida Acad. Sci., **20** (2). Gainesville, 1957.
Wald, G., & Hubbard, R. "Visual pigment of a decapod crustacean: the lobster". Nature, **180** (4580): 278–80. London, 1957.

4) e Flora

Augier, J. "Au sujet de la composition glucidique de *Chondria caerulescens* (Crouan) Falkenb." Bull. Centre Étud. et Rech. Sci. Biarritz, **1** (3): 395–96. Biarritz, 1957.
Boalch, G. T. "Marine algal zonation and substratum in Beer Bay, south-east Devon". J. Mar. Biol. Assoc., **36** (3): 519–28. Cambridge, 1957.
Camba, J. S. "Algas superiores de las rias bajas gallegas". Invest. Pesqu., **8**: 15–28. Barcelona, 1957.
Cavalière, A. "Algologia dello Stretto di Messina. Nota preliminare". Boll. Pesca, Piscicolt. e Idrobiol., **11** (2): 281–82. Roma, 1956.
Gauthier-Lièvre, L. "Le genre *Vaucheria* en Afrique du Nord". Bull. Soc. Hist. Natur. Afrique du Nord, **46**: 309–39. Algérie, 1956.
Gustafsson, U., & Fries, N. "Nutritional requirements of some marine fungi". Physiol. Plantarum, **9**: 462–65. Copenhagen, 1956.
Hampson, M. A. "The laverbread industry in South Wales and the laverweed". MAFF, Fish. Invest., Ser. 2, **21** (7). London, 1957.
Kanwisher, J. "Freezing and drying in inter-tidal algae". Biol. Bull., **113** (2): 275–85. Lancaster, Pa., 1957.
Klemperer, H. G. "The accumulation of iodide by *Fucus ceranoides*". Biochem. J., **67** (3): 381–90. Cambridge, 1957.
Levring, T. "Growth and reproduction in marine algae in different regions". Année Biol., **33**: 57–65. Paris, 1957.
Lück, H. B. "Au sujet d'un cas de formation d'aplanospores dans le genre *Cladophora*". Bull. Inst. Océanogr., **1105**. Monaco, 1957.

Magne, F. "Sur la présence de l'*Halicystis ovalis* (Lyngb.) Areschoug et du *Derbesia marina* (Lyngb.) Kjell. dans la Manche". Bull. Soc. Bot. France, **103** (7/8): 488–90. Paris, 1956.
Meyers, S. P. "Taxonomy of marine pyrenomycetes". Mycologia, **49** (4): 475–528. New York, 1957.
Meyers, S. P. "Incidence of marine fungi in relation to wood-borer attack". Science, **126** (3280): 969. Lancaster, Pa., 1957.
Mohr, J. L., Wilimovsky, N. J., & Dawson, E. Y. "An Arctic Alaskan kelp bed". Arctic, **10** (1): 45–52. Ottawa, 1957.
Odum, E. P. "Uptake of P^{32} in benthic algae in relation to primary productivity". Biol. Bull., **113** (2): 323. Lancaster, Pa., 1957.
Powell, H. T. "Studies in the genus *Fucus* L. II. Distribution and ecology of forms of *Fucus distichus* L. emend. Powell in Britain and Ireland". J. Mar. Biol. Assoc., **36** (3): 663–93. Cambridge, 1957.
Provasoli, L. "Effect of plant hormones on sea weeds". Biol. Bull., **113** (2): 321. Lancaster, Pa., 1957.
Stokke, K. "The red alga *Gracilaria verrucosa* in Norway". Nytt Mag. Bot., **5**: 101–11. Oslo, 1957.
Sundene, O. "Eksperimentelle undersøkelser som kaster lys over benthosalgenes økologi". Blyttia, **14** (3): 78–96. Oslo, 1956.
Taylor, A. R. A. "A survey of Irish moss on Grand Manan in 1955". Fish. Res. Board Canada, Progr. Rep. Atlantic Coast Stat., **67**: 3–5. St. Andrews, 1957.
Taylor, W. R. "Marine algae of the northeastern coast of North America". 2nd. Edit., Univ. Michigan Press, Ann Arbor, 1957.
Tsuda, K., Akagi, S., & Kishida, Y. "Discovery of cholesterol in some red algae". Science, **126** (3279): 927. Lancaster, Pa., 1957.
Werner, R. G. "Réflexions au sujet de la zonation au Maroc". Bull. Soc. Sci. Natur. et Phys. Maroc, **36** (4): 319–33. Rabat, 1956.

4) f Bacteria

Courington, D. P., & Goodwin, T. W. "A survey of the pigments of a number of chromogenic marine bacteria, with special reference to the carotenoids". J. Bacteriol., **70** (5): 568–71. Baltimore, 1955.
Genovese, S., Pichinoty, F., & Senez, J. C. "Sui batteri solfato-riduttori del lago di Faro". Atti Soc. Peloritana Sci. Fisic., Mat., e Natur., **3**: 303–19. Messina, 1957.
Kriss, A. E., & Markianovich, E. M. "Observations on the rate of multiplication of microorganisms in the depths of the sea". Mikrobiologiia, **23** (5): 551–60. Moscow, 1954.
Lalou, C. "Étude expérimentale de la production de carbonates par les bactéries des vases de la baie de Villefranche-sur-mer". Ann. Inst. Océanogr., **33** (4). Paris, 1957.
Lalou, C. "Studies on bacterial precipitation of carbonates in sea water". J. Sediment. Petrol., **27**: 190–95. Tulsa, Okl., 1957.
MacLeod, R. A., & Onofrey, E. "Nutrition and metabolism of marine bacteria. II. Observations on the relation of sea water to the growth of marine bacteria". J. Bacteriol., **71** (6): 661–67. Baltimore, 1956.
Merkel, J. R., Carlucci, A. F., & Pramer, D. "Respiratory characteristics of marine bacteria". Nature, **180** (4600): 1489. London, 1957.
Morita, R. Y., & Howe, R. A. "Phosphatase activity by marine bacteria under hydrostatic pressure". Deep-Sea Res., **4**: 254–58. London & New York, 1957.
Sreenivasan, A. "Nitrate-reducing bacteria from marine environment". Current Sci., **26** (12): 392. Bangalore, 1957.
Taga, N. "Preliminary studies on the removal of radioactive substances from polluted waters by biological methods. On the capacity of water bacteria for adsorption of fission products". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1245–50. Tokyo, 1956.
Vargues, H. "Étude des organismes nitrificateurs des 'Mattes' de Castiglione". Trav. Stat. Aquicult. et Pêche Castiglione, **8**: 59–71. Castiglione, 1957.
Zobell, C. E. "The occurrence of bacteria in the deep sea and their significance for animal life". Internat. Union Biol. Sci., Ser. B, **16**: 20–26. Naples, 1954.

5) Fishing

5) a Statistical Returns

Anon. "Lista de embarcaçoes das pescas industriais". Publ. Gabinete Estud. Pescas, **32**. Lisboa, 1956.

Anon. "Herring – North Sea 1955". ICES, Statist. News Letters, **1**. Copenhagen, 1957.

Anon. "Bulletin Statistique des Pêches Maritimes des pays du nord et de l'ouest de l'Europe. Vol. XL, 1955". ICES, Copenhague, 1957.

Anon. "Yearbook of fishery statistics. Vol. VI, 1955–56". FAO, Rome, 1957.

Anon. "Sea fisheries statistical tables 1956". HMSO, London, 1957.

Anon. "The British fishing industry: comprehensive review of the past twelve months". Fish. Year Book & Direct. 1957: 47–58. London, 1957.

Anon. "Fiskeriberetning for Året 1956". København, 1957.

Anon. "Jaarcijfers over de Visserij gedurende het jaar 1956". Versl. Med. Direct. Viss., **48**. 's-Gravenhage, 1957.

Anon. "Diagnose-rapport visserij, 1956 (voorlopige berekening van de bedrijfsresultaten van de visserij over 1956)". Rapp. Landbouw.-Econ. Inst., **270**. The Hague, 1957.

Anon. "Fiskeflåten 1956". Årsb. Vedk. Norges Fisk., 1956 (13). Bergen, 1957.

Anon. "Norges fiskerier 1955". Norges Offis. Statist., **11** (275). Bergen, 1957.

Anon. "Statistisk årbok for Norge 1957". Norges Offis. Statist., **11** (279). Bergen, 1957.

Anon. "Resumo estatistico das pescas Portuguesas 1938–1956". Publ. Gabinete Estud. Pescas, **34**. Lisboa, 1957.

Anon. "El año pesquero español a través de la estadistica". Industr. Pesqu., **31** (721–722): 92–98. Vigo, 1957.

Anon. "La pesca maritima española en 1956". Industr. Pesqu., **31** (721–722): 100–08. Vigo, 1957.

Anon. "Species composition and distribution of landings of fish and other products in the U.S.S.R.". Rybn. Khoz., 1957 (8): 93–95. Moscow, 1957.

Anon. "Landings of fishes and marine mammals for 1956". Rybn. Khoz., 1957 (2): 90. Moscow, 1957.

Anon. "Statistiques des régions de pêche 1956". Rev. Trav. Inst. Pêches Marit., **21** (3): 439–44. Paris, 1957.

Anon. "Seefischerei und Fischversorgung im Jahre 1956". Stat. Bundesrepublik Deutschland, **178**. Wiesbaden, 1957.

Christiansen, C. "Denmark's fishing industry". Fish. Year Book & Direct. 1957: 83–89. London, 1957.

Fernandez, A. "Dialogo con la estadística". Industr. Pesqu., **31** (732): 9–10. Vigo, 1957.

de Figueiredo, J. M. "O factor de conversao e indices de aproveitamento do bacalhau a bordo. Resultados dos ensaios feitos na frota bacalhoeira portuguesa, nas aguas da Terra Nova e Gronelandia, durante a campanha de 1953". Publ. Gabinete Estud. Pescas, **22**. Lisboa, 1954.

de Figueiredo, J. M. "O factor de conversao e indices de aproveitamento. Resultados dos estudos feitos com o bacalhau das aguas da Costa do Labrador, em 1953". Publ. Gabinete Estud. Pescas, **23**. Lisboa, 1954.

Friis, K. "Norges Fiskerier 1956". Fiskets Gang, 1957 (49): 609–15. Bergen, 1957.

Hass, G. "Vergleich der Fangleistungen deutscher Fischdampfer und Fischereimotorschiffe unter besonderer Berücksichtigung von Grösse, Maschinenstärke und Alter". Protok. Fischereitechn., **4** (19): 126–52. Hamburg, 1957.

Holm, A. "Stortrålernes lønnsomhet 1956". Fiskets Gang, 1957 (46): 554–59. Bergen, 1957.

Holm, A. "Småtrålernes lønnsomhet 1956". Fiskets Gang, 1957 (48): 593–98. Bergen, 1957.

Lundbeck, J. "Biologisch-statistischer Bericht über die deutsche Hochseefischerei im Jahr 1956". Jahresber. Deutsche Fisch., 1956: 121–51. Berlin, 1957.

Martin, W. R., & Sullivan, G. J. W. "1953 landings of Atlantic groundfish in Canada (excluding Newfoundland)". Fish. Res. Board Canada, Atlantic Biol. Stat., Statist. Ser. Circ., **7**. St. Andrews, 1957.

Meseck, G. "Western Germany's fishing industry". Fish. Year Book & Direct. 1957: 73–82. London, 1957.

Mollestad, S. "Småtrålernes fiske i 1956". Fiskets Gang, 1957 (47): 575–81. Bergen, 1957.

Predel, G. "Die wirbellosen Fischereiobjekte des Meeres und ihre Bedeutung für die Fischerei". Deutsche Fisch. Zeit., 1957 (8): 231–33. Radebeul, 1957.

Sullivan, G. J. W., & Martin, W. R. "1952 landings of fresh groundfish by offshore vessels at Nova Scotia ports". Fish. Res. Board Canada, Atlantic Biol. Stat., Statist. Ser. Circ., **6**. St. Andrews, 1955.
Witje, J. A. P. "25 jaar IJsselmeer". Visserij-Nieuws, **10** (3): 34–36. 's-Gravenhage, 1957.

5) b Vessels

Anon. "Polnische Fischdampfer". Hansa, **93** (44/45): 2117. Hamburg, 1956.
Anon. "Hydroconic hull: power with economy". Fishing News, 1957 (2319): 7. London, 1957.
Anon. "Le deuxième chalutier diesel-électrique anglais: le 'Cape Trafalgar'". Pêche Marit., **955**: 451–55. Paris, 1957.
Anon. "Le nouveau navire-usine allemand 'Carl Kampf'". Pêche Marit., **36** (956): 511–13. Paris, 1957.
Loureiro, G. C. de A. "A historia de um navio o 'Gil Eanes'". Publ. Gabinete Estud. Pescas, **33**. Lisboa, 1956.
Ridgely-Nevitt, C. "The resistance of trawler hull forms of 0.65 prismatic coefficient". Trans. Soc. Naval Archit. & Mar. Engin., **64** (November). New York, 1957.

5) c Gear

Ahmad, N. "Fishing gear of East Pakistan". Govt. East Pakistan, Direct. Fish., Dacca, 1956.
Anon. "A arte de Palangre na pesca nacional do bacalhau". Publ. Gabinete Estud. Pescas, **10**. Lisboa, 1953.
Anon. "North Atlantic fisheries exploration and gear research". Commerc. Fish. Rev., **18** (10): 24. Washington, 1956.
Anon. "Mediterranean trawling preliminary observations in the study of Italian trawl nets". FAO, Gen. Fish. Counc. Mediterranean, Stud. & Rev., **2**. Rome, 1957.
Anon. "Echo sounding in East Anglia – it works". MAFF Lab. Leafl., **17**. Lowestoft, 1957.
Anon. "Asdics for fish detection". World Fishing, **6** (10): 84–86. London, 1957.
Anon. "A new technique for electrial fishing". Commerc. Fish. Rev., **19** (7): 32. Washington, 1957.
Anon. "Fish behaviour in cod ends studied with underwater television (M/V 'Albatross III', Cruise 96)". Commerc. Fish. Rev., **19** (8): 29. Washington, 1957.
Anon. "De 'Vragenrubriek'". Visserij-Nieuws, **10** (3): 36–41. 's-Gravenhage, 1957.
Anon. "Elektrofischerei". Wiss. Inform. Fischereipraxis, **4** (4): 101. Bremerhaven, 1957.
Azhazha, V. G. "On the fish-seeking qualities of certain echo-sounders". Rybn. Khoz., 1956 (11): 11–17. Moscow, 1956.
von Brandt, A., & Rutkowski, F. "Fischereigeräte der Binnenfischerei, ihr Bau, ihre Rohstoffe und ihre Behandlung". Arb. Deutschen Fisch.-Verbandes (6). Hamburg, 1956.
Breitenstein, W. "Reusen der Binnenfischerei". Deutsche Fisch. Zeit., 1957 (11): 343–49. Radebeul, 1957.
Breitenstein, W. "Betrachtungen über Reusen der Binnenfischerei unter besonderer Berücksichtigung der Benennung, der Anfertigungsmethoden und der Normierung". Zeitschr. Fisch. Hilfswiss., **5** (5/6): 443–76. Berlin, 1957.
Bulmahn, A. "Gerät zum Einstellen gleicher Kurrleinenlängen bei Schleppnetzen". Fischereiwelt, **9** (7): 57. Bremerhaven, 1957.
Carrothers, P. J. G. "The selection and care of nylon gill nets for salmon". Fish. Res. Board Canada, Techn. Stat. Vancouver, Industr. Mem., **19**. Vancouver, 1957.
Chevalier, R. "La langouste verte. Sa pêche par les Douarnenistes". Sci. et Pêche, Ser. B, **48**. Paris, 1957.
Chigusa, M., *et al.* "Studies on the configuration of purse seine – I. On the variations of the configuration due to the shrinkage at the wing sides of the purse seine". J. Shimonoseki College Fish., **6** (3): 285–90. Shimonoseki City, 1957.
Datingaling, B. Y. "Fishing with 'Bombon' in Batangas Province". Bull. Fish. Soc. Philippines, **3** & **4**: 41–44. Manila, 1952–1953.
Datingaling, B. Y., & Bunag, D. M. "Mechanization of the Pukot-Panulingan (half-ring net)". Bull. Fish. Soc. Philippines, **2**: 63–70. Manila, 1951.
Dickie, L. M., & MacPhail, J. S. "An experimental mechanical shellfish-digger". Progr. Rep. Atlantic Coast Stat., **66**: 3–8. St. Andrews, N. B., 1957.

Eddie, G. C. "Quick-freezing at sea". Modern Fishing, Fishing News, 1957 (October Supplem.): 24 & 26. London, 1957.
Eitzen, J. "Das Vierscherbrett-Schwimmschleppnetz". Fischereiwelt, **9** (8): 61–62. Hamburg, 1957.
Ferrer, G. G. "Rigging of motor vessels as basnigan". Bull. Fish. Soc. Philippines, **2**: 28–40. Manila, 1951.
Forsyth, W. S. "How to make lobster creels more escape-proof". Fishing News (2317): 9. London, 1957.
Friedman, S. L. "Horizontal opening of the trawl in stern trawling". Rybn. Khoz., 1957 (7): 33–34. Moscow, 1957.
Ganekov, A. A. "Experimental use of hydro-acoustic instruments in the capture of herrings with the midwater trawl". Rybn. Khoz., 1957 (6): 57–63. Moscow, 1957.
Glanville, A. "British fishing in practice. Constructive review of various methods to secure maximum efficiency". Modern Fishing, Fishing News, 1957 (October Supplem.): 7 & 9. London, 1957.
Gollub, H. "Fragen der Elektrofischerei". Deutsche Fisch. Zeit., 1957 (9): 274. Radebeul, 1957.
Gottlieb, E., & Oren, O. H. "Savings gear experiments with trawl nets in Israel waters". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 281–87. Rome, 1957.
Halme, E. "Kalamiesten Niksikirja". Werner Söderström Osakeyhtio Porvoo, Helsinki, 1955.
Isouti, N., & Kawakami, T. "Mechanical studies on the trolling gear. I. Estimation of the fishing depth". Mem. College Agric. Kyoto Univ., **76**: 1–7. Kyoto, 1957.
Itaka, Y. "Study on the fishing capacities of purse seines. II. On difference between single and double purse seines operating in Wakasa Bay". Bull. Japanese Soc. Sci. Fish., **23** (1): 24–26. Tokyo, 1957.
Kajewski, G. "Beiträge zur Perlon-Frage". Deutsche Fisch. Zeit., 1957 (6): 161–66. Radebeul, 1957.
Koyama, T. "Study on bait for tuna long line. I. An artificial bait of latex sponge shaped like a squid". Bull. Tokai Reg. Fish. Res. Lab., **15**: 89–94. Tokyo, 1957.
Kunze, W. "General aspects of application of horizontal echo sounding method to shipping". Internat. Hydrogr. Rev., **34** (2): 63–72. Monaco, 1957.
Kusaka, T. "Experiments to see the different effects of net on driving several species of fish". Bull. Japanese Soc. Sci. Fish., **23** (1): 1–5. Tokyo, 1957.
MacPherson, H. D. "Profitable long-lining for cod". Canadian Fisherman, **43** (3): 14. Montreal, 1956.
Manacop, P. R., & Laron, S. V. "Two outstanding commercial fishing gear of the Philippines". Bull. Fish. Soc. Philippines, **3** & **4**: 73–84. Manila, 1952–1953.
Margetts, A. R. "The length-girth relationships in whiting and cod and their application to mesh selection". ICES, J. Cons., **23** (1): 64–71. Copenhague, 1957.
Miyamoto, H. "Hydrodynamic resistance of a plane net". Internat. Shipbuilding Progr., **2** (11): 291. Rotterdam, 1955.
Miyamoto, H. "Behaviour of fishes entering trap nets". Bull. Tokai Reg. Fish. Res. Lab., **15**: 77–87. Tokyo, 1957.
Molin, G. "Nätmontering och fisklighet". Svensk Fisk. Tidskr., **66** (2): 30. Lund, Sweden, 1957.
Moritz, W. "Durch die Anwendung der neuen Technik zu grösseren Fangerträgen in der Küstenfischerei'. Deutsche Fisch.-Zeit., 1956 (2): 33. Radebeul, 1956.
Mosher, F. D. "Mechanical net lifters speed fishing operations". National Fisherman, **37** (2): 17. USA, 1956.
Noel, H. S. "Some aspects of potting". World Fishing, **6** (9): 59–63. London, 1957.
Noel, H. S. "Design and operation of the Thames floating sprat trawl". World Fishing, **6** (10): 62–66. London, 1957.
Nomura, M., & Mori, K. "Resistance of plane net against flow of water. V. On the inclination of net in a current". Bull. Japanese Soc. Sci. Fish., **21** (11): 1114–20. Tokyo, 1956.
Nomura, M., *et al.* "On the horizontal distribution of catch influenced by the seam of net in sardine drift nets". Bull. Japanese Soc. Sci. Fish., **23** (5): 245–48. Tokyo, 1957.
Okawa, T. "Trial production of a circulating water tank". Bull. Fac. Fish. Hokkaido Univ., **8** (1): 45–47. Hakodate, 1957.
van Pel, H. "Depth trolling off Tonga". Quart. Bull. South Pacific Commiss., **5** (3): 15–16. Noumea, New Caledonia, 1955.

Ponomarev, F. A. "An experiment (on stake nets) by the fishermen of Pechova". Rybn. Khoz., 1956 (11): 42–45. Moscow, 1956.
Powell, D. E. "North Pacific albacore tuna exploration by the M/V 'John N. Cobb' – 1956". Commerc. Fish. Rev., **19** (6): 1–9. Washington, 1957.
Rahn, J. "Nochmals: Fragen der Elektrofischerei". Deutsche Fisch.-Zeit., 1957 (11): 334–38. Radebeul, 1957.
Rasalan, S. B., & Datingaling, B. Y. "Fish corral fishing in the Philippines". Bull. Fish. Soc. Philippines, **3** & **4**: 45–63. Manila, 1953.
Rasalan, S. B., & Datingaling, B. Y. "Fishing with artificial light in the Philippines". Bull. Fish. Soc. Philippines, **3** & **4**: 64–72. Manila, 1953.
Riedel, D. "Zur Frage einer eventuellen Schädigung von Fischbrut und Fischgeschlechtsprodukten sowie von Fischnährtieren durch den elektrischen Strom bei der Elektrofischerei". Deutsche Fisch.-Zeit., 1955 (1): 20–22. Radebeul, 1955.
Robas, J. S. "Construction and use of prawn trawl try-net". Fish. Newsletter, **15**: 5, 7, 9, & 11. Sydney, 1956.
Robas, J. S. " Anew deep-water shrimp fishery. American shrimpers fit European equipment". World Fishing, **6** (8): 38–40. London, 1957.
Ryzhenko, M. I. "Capture of herrings by the mid-water trawl". Rybn. Khoz., 1957 (5): 14-18. Moscow, 1957.
Schärfe, J. "Über Messungen zur Kontrolle von Schleppnetzen". Fischereiwelt, **9** (9): 75–77. Hamburg, 1957.
Schärfe, J. "Small echo-sounders for the coastal fisheries". Allg. Fischwirtschaftzeit.. 1957 (21). München, 1957.
Schlieker, E. "Hinweise zur Fischerei mit Grossreusen". Deutsche Fisch.-Zeit., 1957 (5): 129–39. Radebeul, 1957.
Shabanov, A. N. "On types of herring trawls". Rybn. Khoz., 1957 (1): 22–25. Moscow, 1957.
Skrebets, V. K. "On herring trawls in the North Sea". Rybn. Khoz., 1957 (1): 16–19. Moscow, 1957.
Smith, K. A. "Maine herring explorations and fishing gear experiments". Commerc. Fish. Rev., **19** (9): 1–15. Washington, 1957.
Smyslov, I. G. "Balancing the mid-water trawl during trawling". Rybn. Khoz., 1957 (3): 79–81. Moscow, 1957.
Steinberg, R. "Die Treibzeesenfischerei im Gebiet von Stralsund". Protok. Fischereitechn., **4** (20): 175–208. Hamburg, 1957.
Süberkrüb, F. "Seitenscherbretter für pelagische Schleppnetze". Fischereiwelt, **9** (9): 78–79. Hamburg, 1957.
Tapiador, D. D. "A report on deepsea longline fishing for tuna in the Philippines". Bull. Fish. Soc. Philippines, **2**: 3–27. Manila, 1951.
Thomas, H. J. "Lobster and crab pots: Scottish creel, Nova Scotia trap, Cornish pot, Gourdon crab pot, and Wollaston's collapsible pot". Scottish Home Dept., Aberdeen, 1956.
Vibert, R. "Aperçu sur le problème des grilles et de leur nettoyage". Bull. Français Piscicult., **183**: 45–64. Paris, 1956.
Vives, F., & Suau, P. "Sur la régénération des fonds de pêche du Levant espagnol". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 197–206. Rome, 1957.

5) d Grounds and Fishing Surveys

Anon. "Contribuiçao da pesca do arrasto para o abastecimento alimentar do pais". Publ. Gabinete Estud. Pescas, **29**. Lisboa, 1956.
Anon. "90,000 tons of sand eels". World Fishing, **6** (9): 39–41. London, 1957.
Faure, L. "La première campagne 1957 du navire océanographique 'Président Théodore Tissier'". Sci. et Pêche, Ser. A, **50**. Paris, 1957.
Ishkov, A. A. "Development of the fishing industry in 40 years of Soviet authority". Rybn. Khoz., 1957 (11): 9–19. Moscow, 1957.
June, F. C., & Reintjes, J. W. "Survey of the ocean fisheries off Delaware Bay". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **222**. Washington, 1957.
de Lemos, J. "Alguns aspectos da pesca e dos pescadores da Orla Continental Portuguesa. (Extractos dum Relatorio)". Publ. Gabinete Estud. Pescas, **27**. Lisboa, 1955.
Pascal, H. "Considérations sur les pêches maritimes en Oranie". Pêche Marit., **36** (954): 389–91. Paris, 1957.
Postel, E. "La pêche en Tunisie". Pêche Marit., **36** (953): 348–51. Paris, 1957.

5) e Technology

ANON. "Report on an experiment into the freezing of fish at sea". White Fish Authority, London, 1957.

EREMBITOV, F. Z. "Experimental working with fish-freezing ships of the 'Druzhba' type". Rybn. Khoz., 1957 (7): 13–16. Moscow, 1957.

HARRISON, J. S. N., & ROACH, S. W. "Application of refrigerated seawater fish holding to a halibut fishing vessel". Fish. Res. Board Canada, Progr. Rep. Pacific Coast Stat., **108**: 10–14. Nanaimo, 1957.

SHEWAN, J. M. "Experiments with antibiotics and antibacterial substances in the preservation of white fish and fillets". Modern Refrigeration, **59**: 423–25. London, 1956.

STERN, J. A., *et al.* "Comparative studies of the effects of the tetracycline group of antibiotics in the preservation of fish". Antibiotics Ann. 1956–1957: 984–96. New York, 1957.

TERENTIEV, A. V. "40 years' development of fishery technology of the U.S.S.R." Rybn. Khoz., 1957 (11): 31–39. Moscow, 1957.

6) Fish

6) a Cod

ANON. "Undersøkelser i Lofoten". Årsb. Vedk. Norges Fisk., 1956 (9): 27–38. Bergen, 1957.

ANON. "La disparition de la morue aux îles Lofoten". Pêche Marit., **36** (956): 498. Paris, 1957.

BERNER, M. "Lassen sich die Dorschfänge in der Ostsee steigern?" Deutsche Fisch.-Zeit., 1957 (9): 258–62. Radebeul, 1957.

ENGER, P. S. "The electroencephalogram of the codfish (*Gadus morrhua*). Spontaneous electrical activity and reaction to photic and acoustic stimulation". Acta Physiol. Scandinavica, **39**: 55–72. Stockholm, 1957.

FIGUERAS, A. "Datos sobre la edad y crecimiento del bacalao (*Gadus callarias* L.) de Terranova". Invest. Pesqu., **8**: 3–14. Barcelona, 1957.

FRØLAND, A. "Forsøksfiske med snurpenot etter torsk ved Vest-Grønland 1956". Årsb. Vedk. Norges Fisk., 1956 (9): 47–55. Bergen, 1957.

GEORGALA, D. L. "Changes in the skin flora of cod after washing and icing". J. Appl. Bacteriol., **20** (1): 23–29. Reading, 1957.

HILL, H. W., & LEE, A. J. "The effect of wind on water transport in the region of the Bear Island fishery". Proc. Roy. Soc., Ser. B, **148** (930): 104–16. London, 1958.

HODGKISS, W., & JONES, N. R. "The free amino acids of fish. Post mortem changes in sterile skeletal muscle of North Sea codling". Biol. J., **61** (1): IV. London, 1955.

HOOGLAND, P. L. "The B-vitamins of cod and haddock". Stud. Stat. Fish. Res. Board Canada, **439**. Ottawa, 1956.

KISELEV, O. N. "On the distribution and behaviour of Barents Sea cod and haddocks". Rybn. Khoz., 1957 (5): 62–65. Moscow, 1957.

LEIVESTAD, H., ANDERSEN, H., & SCHOLANDER, P. F. "Physiological response to air exposure in codfish". Science, **126** (3272): 505. Lancaster, Pa., 1957.

MCCRACKEN, F. D. "Results of cod tagging off eastern Nova Scotia". Progr. Rep. Atlantic Coast Stat., **67**: 6–13. St. Andrews, N. B., 1957.

NUNES-RUIVO, L. "Contribution à l'étude des variations morphologiques de *Clavella adunca* (H. Ström), copépode parasite de *Gadus callarias* L. Considérations sur quelques *Clavella* parasites des Gadidae". Rev. Fac. Ciênc., 2 A, Ser. C, Ciênc. Natur., **5** (2): 229–56. Lisboa, 1957.

PINEDA, M. D. G. "Estudio de los lipidos de la carne del bacalao (*Gadus callarias* L.)". Trab. Inst. Español Oceanogr., **23**. Madrid, 1957.

ROKSTAD, G. "Forsøksfiske med M/S 'Thor Iversen' ved Bjørnøya, Svalbard og i Barentshavet 1956". Årsb. Vedk. Norges Fisk., 1956 (9): 42–46. Bergen, 1957.

RUIVO, M. "Contribuiçao para o estudo das relaçoes entre os comprimentos do bacalhau ('*Gadus callaris* L.') inteiro, escalado e 'verde', pescado na Terra-Nova". Bol. Pesca, **11** (55): 91–97. Lisboa, 1957.

SCHOLANDER, P. F., VAN DAM, L., & ENNS, T. "The source of oxygen secreted into the swimbladder of cod". J. Cell. & Comp. Physiol., **48** (3): 517–22. Philadelphia, 1956.

SCOTT, D. M., & MARTIN, W. R. "Variation in the incidence of larval nematodes in Atlantic cod fillets along the southern Canadian mainland". J. Fish. Res. Board Canada, **14** (6): 975–96. Ottawa, 1957.

Squires, H. J. "Cod eggs and herring larvae in late September an indication of fall spawning in the Gulf of St. Lawrence". Fish. Res. Board Canada, Progr. Rep. Atlantic Coast Stat., **67**: 31–33. St. Andrews, 1957.

Trout, G. C. "The Bear Island cod migrations and movements". MAFF, Fish. Invest., Ser. 2, **21** (6). London, 1957.

Wiborg, K. F. "Factors influencing the size of the year classes in the Arcto-Norwegian tribe of cod". Fiskeridirekt. Skr., Ser. Havunders., **11** (8). Bergen, 1957.

6) b Haddock

Brenner, R. R. "Fish lipides. The acid lipides present in an acetone muscle extract of *Gadus aeglefinus*". An. Asoc. Quim. Argentina, **44**: 210–25. Buenos Aires, 1956.

Clark, J. R. "Georges Bank haddock fishery – changes in scrod abundance in recent years". Commerc. Fish. Rev., **18** (10): 1–3. Washington, 1956.

Hoogland, P. L. "The B-vitamins of cod and haddock". Stud. Stat. Fish. Res. Board Canada, **439**. Ottawa, 1956.

Kabata, Z. "*Lernaeocera obtusa* n. sp., a hitherto undescribed parasite of the haddock (*Gadus aeglefinus*)". J. Mar. Biol. Assoc., **36** (3): 569–92. Cambridge, 1957.

Kiselev, O. N. "On the distribution and behaviour of Barents Sea cod and haddocks". Rybn. Khoz., 1957 (5): 62–65. Moscow, 1957.

Rae, K. M. "A relationship between wind, plankton distribution and haddock brood strength". Bull. Mar. Ecol., **4** (38): 247–69. Edinburgh, 1957.

6) c Hake

Matta, F. "Accrescimento ponderale del merluzzo del Mediterraneo (*Merluccius merluccius* L.)'. Boll. Pesca, Piscicolt. et Idrobiol., **11** (2): 283–90. Roma, 1956.

Zenkewitch, L. A. "Erforschungen der Tiefseefauna im nordwestlichen Teil des Stillen Ozeans '. Internat. Union Biol. Sci., Ser. B, **16**: 72–85. Naples, 1954.

6) d Plaice

Jakolev, V. "Vorläufige Mitteilung über die Untersuchung des Wassergehaltes bei Schollen und Klieschen". Kurze Mitt. Inst. Fischerei Biol. Univ. Hamburg, 1957 (7): 23–28. Hamburg, 1957.

Kabata, Z. "Note on a new host of *Myxobolus aeglefini*". Parasitol., **47** (1 & 2): 165–67. Cambridge, 1957.

Molander, A. R., & Molander-Swedmark, M. "Experimental investigations on variation in plaice (*Pleuronectes platessa* Linné)". Rep. Inst. Mar. Lysekil, Ser. Biol., **7**. Lund, 1957.

Shelbourne, J. E. "The feeding and condition of plaice larvae in good and bad plankton patches". J. Mar. Biol. Assoc., **36** (3): 539–52. Cambridge, 1957.

6) f Halibut

Anon. "Regulation and investigation of the Pacific halibut fishery in 1956". Internat. Pacific Halibut Commiss., **25**. Seattle, 1957.

Moiseev, P. A. "New data concerning distribution of the halibut". Doklady Akad. Nauk SSSR, **105** (2): 374–75. Moscow, 1955.

6) g Other Marine Demersal Species

Andriashev, A. P. "A gadfish species (*Arctogadus glacialis* (Peters)) new to the fauna of the U.S.S.R. caught at the drifting station 'North Pole-6'". Zool. Zhurn., **36** (11): 1747. Moscow, 1957.

Anon. "Biologists tag first ocean perch". Commerc. Fish. Rev., **18** (10): 28. Washington, 1956.

Anon. "Zandspieringvisserij in de Nordzee". Visserijwereld, **16** (48): 17–18. 's-Gravenhage, 1957.

Briggs, J. C., & Caldwell, D. K. "*Acanthurus randalli*, a new surgeon fish from the Gulf of Mexico". Bull. Florida State Mus., Biol. Sci., **2** (4): 43–52. USA, 1957.

Clements, M. "The proteolytic activity of the thyroid and other tissues of the dogfish, *Scyliorhinus* (*Scyllium*) *canicula*". Bull. Inst. Océanogr., **1091**. Monaco, 1957.

Dieuzeide, R. "Les myxines (*Myxine glutinosa* L.) en Méditerranée". Trav. Stat. Aquicult. et Pêche Castiglione, N. S., **8**: 73–80. Castiglione, 1957.

Dollfus, R. P., & Campana-Rouget, Y. "Une nouvelle espèce d'*Ascarophis* (Nematoda, Spirurinae) chez *Gadus luscus* L. Révision du genre". Ann. Parasitol. Humaine et Comp., **31** (4): 385–404. Paris, 1956.

Gottlieb, E. "The age and growth of the red mullet *Mullus barbatus* L. in Israel waters 1953–1955". Bull. Sea Fish. Res. Stat., **12**. Haifa, 1956.

Hass, G. "Die Fischerei auf Sandspierlinge. Ein neuer Betriebszweig der Kleinen Hochseefischerei". Fischereiwelt, **9** (10): 85–86. Hamburg, 1957.

Holland, G. A. "Migration and growth of the dogfish shark, *Squalus acanthias* (Linnaeus), of the eastern north Pacific Ocean". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 43–59. Washington, 1957.

Jakolev, V. "Vorläufige Mitteilung über die Untersuchung des Wassergehaltes bei Schollen und Klieschen". Kurze Mitt. Inst. Fisch. Biol. Univ. Hamburg, 1957 (7): 23–28. Hamburg, 1957.

Kanazawa, R. H. "A new species of eel, *Coloconger meadi*, and new records for the ateleopid fish. *Ijimaia antellarum* Howell Rivero, both from the Gulf of Mexico". Copeia, 1957 (3): 234–35. Baltimore, 1957.

Krumholz, L. A. "A record of the night shark, *Hypoprion signatus*, from Bimini, Bahamas". Copeia, 1957 (4): 300. Baltimore, 1957.

Leary, T. R. "The bonefish, *Albula vulpes*, in Texas". Copeia, 1957 (3): 248. Baltimore, 1957.

Lewis, R. M. "Comparative study of populations of the striped bass". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **204**. Washington, 1957.

Mead, G. W. "An Atlantic record of the zeoid fish *Parazen pacificus*". Copeia, 1957 (3): 235–37. Baltimore, 1957.

Monteiro, R. "Études sur la biologie de la famille des Triglidae. II. *Trigla lineata* Gmelin de la région de Banyuls". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 37–42. Rome, 1957.

Rae, B. B. "A preliminary account of the turbot in Scottish waters". Scottish Fish. Bull., **8**: 10–12. Edinburgh, 1957.

Raney, E. C. "Populations of the striped bass. *Roccus saxatilis* (Walbaum) in tributaries of Chesapeake Bay". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 85–107. Washington, 1957.

Sandeman, E. J. "Redfish grow slowly". Fish. Res. Board Canada, Progr. Rep. Atlantic Coast Stat., **67**: 26–28. St. Andrews, 1957.

Seydlitz, H. "Ein Fund von *Anarrhichas*-Larven". Kurze Mitt. Inst. Fischerei Biol. Univ. Hamburg, 1957 (7): 40–44. Hamburg, 1957.

Shoemaker, H. H. "Observation of bioluminescence in the Atlantic fish (*Porichthys porosissimum*)". Science, **126** (3283): 1112. Lancaster, Pa., 1957.

Springer, S., & Thompson, J. R. "Night sharks, *Hypoprion*, from the Gulf of Mexico and the Straits of Florida". Copeia, 1957 (2): 160. Baltimore, 1957.

Steele, D. H. "The redfish (*Sebastes marinus* L.) in the western Gulf of St. Lawrence". J. Fish. Res. Board Canada, **14** (6): 899–924. Ottawa, 1957.

Suau, P., & Vives, F. "Contribución al estudio del salmonete de fango (*Mullus barbatus* L.) del Mediterráneo occidental". Invest. Pesqu., **9**: 97–118. Barcelona, 1957.

Sundnes, G. "Notes on the energy metabolism of the cod (*Gadus callarias* L.) and the coalfish (*Gadus virens* L.) in relation to body size". Fiskeridirekt. Skr., Ser. Havunders., **11** (9). Bergen, 1957.

Templeman, W. "Redfish exploration north of Flemish Cap". Progr. Rep. Atlantic Coast Stat., **67**: 14–18. St. Andrews, N. B., 1957.

Templeman, W. & Sandeman, E. J. "Two varieties of redfish in the Newfoundland area". Progr. Rep. Atlantic Coast Stat., **66**: 20–23. St. Andrews, N. B., 1957.

Tucker, D. W. "Studies on the Trichiuroid fishes. IV. A specimen of *Evoxymetopon taeniatus* (Poey) Gill, from the Gulf of Mexico". Ann. & Mag. Natur. Hist., **10** (114): 425–28. London, 1957.

Tucker, D. W., & Newnham, C. T. "The blue shark *Prionace glauca* (L.) breeds in British seas". Ann. & Mag. Natur. Hist., Ser. 12, **10** (117): 673–88. London, 1957.

Walters, V. "*Alphestes scholanderi*, a new sea bass from the West Indies". Copeia, 1957 (4): 283–86. Baltimore, 1957.

Ward, J. W. "The reproduction and early development of the sea catfish, *Galeichthys felis*, in the Biloxi (Missippi) Bay". Copeia, 1957 (4): 295–98. Baltimore, 1957.

Wickler, W. "Die Larve von *Blennius fluviatilis* Asso 1784". Biol. Zentralbl., **76** (4): 453–66. Leipzig, 1957.

Willgohs, J. F. "Some notes on *Beryx decadactylus* (Cuv. & Val.) in European waters with a special account of Norwegian records". Univ. Bergen Årbok, 1956, Naturvit. rekke (15). Bergen, 1957.

Woods, L. P. "*Beryx splendens* Lowe in the Gulf of Mexico". Copeia, 1957 (4): 298–99. Baltimore, 1957.

Wundsch, H. "Einiges über lebendgebärende Fische". Deutsche Fisch.-Zeit., 1957 (2): 44–48. Radebeul, 1957.

6) h Herring

Anon. "Herring – North Sea 1955". ICES, Statist. News Letters, **1**. Copenhagen, 1957.

Anon. "Overfishing of herring. Unlimited fishery disturbs natural equilibrium". Holland Fish Trade, 1957 (23): 1–3. 's-Gravenhage, 1957.

Balls, R. "Overfishing or overfeeding? (1). A study of East Anglian fishing changes". World Fishing, **6** (11): 58, 60, & 62. London, 1957.

Bhattacharyya, R. N. "The food and feeding habits of larval and post-larval herring in the northern North Sea". Mar. Res., Scottish Home Dept. (3). Edinburgh, 1957.

Cushing, D. H., & Burd, A. C. "On the herring of the southern North Sea". ICES, R. et P.-V., **143** (1): 26–28. Copenhague, 1957.

Day, L. R. "Populations of herring in the northern Gulf of St. Lawrence". Bull. Fish. Res. Board Canada, **111**: 103–19. Ottawa, 1957.

Day, L. R. "Populations of herring in the southern Gulf of St. Lawrence". Bull. Fish. Res. Board Canada, **111**: 121–37. Ottawa, 1957.

Day, L. R. "Vertebral numbers and first-year growth of Canadian Atlantic herring (*Clupea harengus* L.) in relation to water temperature". Bull. Fish. Res. Board Canada, **111**: 165–76. Ottawa, 1957.

Dmitriev, J., & Achlinov, I. "Reorganization of the herring fishery in the North Atlantic". Rybn. Khoz., 1956 (11): 17–19. Moscow, 1956.

Dragesund, O., & Ljøen, R. "Småsild- og feitsildtokt med 'G. O. Sars' i Norskehavet og Barentshavet fra 9. juli til 31. august 1957". Fiskets Gang, 1957 (46): 560–65. Bergen, 1957.

Gilis, C. "Evolution dans le temps et dans l'espace de la composition de harengs exploitées par les pêcheurs belges dans la Mer du Nord au cours de la période 1951–1955". ICES, R. et P.-V., **143** (1): 34–42. Copenhague, 1957.

Gilis, C. "La campagne harenguière 1956–57 (24 juillet 1956 – 19 janvier 1957)". Inst. Etud. Marit., 1957 (1). Ostende, 1957.

Gontarev, J. M. "Work on the herring fishery of the North Atlantic". Rybn. Khoz., 1957 (5): 67–69. Moscow, 1957.

Hamdorf, K. "Das allometrische Wachstum der Wirbelsäule der Heringslarve sowie dessen Auswirkung auf die Verlagerung der paarigen und unpaarigen Flossen". Kurze Mitt. Inst. Fischerei Biol. Univ. Hamburg, 1957 (7): 1–22. Hamburg, 1957.

Kolesnikov, V. G. "The influence of hydrological conditions on the distribution and behaviour of the herring in the Norwegian Sea". Rybn. Khoz., 1957 (11): 69–76. Moscow, 1957.

Leim, A. H. "Summary of results under the Atlantic Herring Investigation Committee". Bull. Fish. Res. Board Canada, **111**: 1–16. Ottawa, 1957.

Leim, A. H. "Fatness of herring in Canadian Atlantic waters". Bull. Fish. Res. Board Canada, **111**: 177–84. Ottawa, 1957.

Leim, A. H., Tibbo, S. N., & Day, L. R. "Explorations for herring in Canadian Atlantic waters, 1945–1950". Bull. Fish. Res. Board Canada, **111**: 35–83. Ottawa, 1957.

Leim, A. H., *et al.* "Report of the Atlantic Herring Investigation Committee". Bull. Fish. Res. Board Canada, **111**. Ottawa, 1957.

Outram, D. N. "Extent of herring spawning in British Columbia waters during 1955". Fish. Res. Board Canada, Pacific Biol. Stat. Circ., **37**. Nanaimo, 1955.

Outram, D. "The development of the Pacific herring egg". Turtox News, **35** (1): 16–22. Chicago, 1957.

Parrish, B. B., & Craig, R. E. "Recent changes in the North Sea herring fisheries". ICES, R. et P.-V., **143** (1): 12–21. Copenhague, 1957.

Schubert, K. "The German herring fisheries in the North Sea and the biological conditions of the Bank herring stock". ICES, R. et P.-V., **143** (1): 29–33. Copenhague, 1957.

Semenov, A. I. "On the choice of fishing grounds (from the experiments in the herring fishery of the North Atlantic)". Rybn. Khoz., 1957 (6): 55–57. Moscow, 1957.
Smith, K. A. "Maine herring explorations and fishing gear experiments". Commerc. Fish. Rev., **19** (9): 1–15. Washington, 1957.
Sokolov, B. G., & Sokolov, G. V. "Drift-nets for catching herrings in the North Atlantic". Rybn. Khoz., 1956 (10): 10–13. Moscow, 1956.
Soloviev, B. S., & Degtiariev, A. A. "Diurnal vertical migrations of the Atlantic-Scandinavian herring before and during its spawning period". Rybn. Khoz., 1957 (11): 81–84. Moscow, 1957.
Squires, H. J. "Cod eggs and herring larvae in late September an indication of fall spawning in the Gulf of St. Lawrence". Fish. Res. Board Canada, Progr. Rep. Atlantic Coast Stat., **67**: 31–33. St. Andrews, 1957.
Taylor, F. H. C. "Prospects for the 1955–56 herring fishing season". Fish. Res. Board Canada, Pacific Biol. Stat. Circ., **38**. Nanaimo, 1955.
Taylor, F. H. C. "Prospects for the 1957–58 herring fishing season". Fish. Res. Board Canada, Pacific Biol. Stat. Circ., **45**. Nanaimo, 1957.
Tibbo, S. N. "Herring of the Chaleur Bay area". Bull. Fish. Res. Board Canada, **111**: 85–102. Ottawa, 1957.
Tibbo, S. N. "Contribution to the biology of herring (*Clupea harengus* L.) on the Atlantic coast of Nova Scotia". Bull. Fish. Res. Board Canada, **111**: 139–51. Ottawa, 1957.
Tibbo, S. N. "Herring populations on the south and west coasts of Newfoundland". Bull. Fish. Res. Board Canada, **111**: 153–64. Ottawa, 1957.
Vikse, H. "Vintersildfisket 1956 (Stor- og vårsildfisket)". Årsb. Vedk. Norges Fisk., 1956 (6). Bergen, 1957.
Zijlstra, J. J. "The catch per unit of effort of the Dutch drift-net fisheries in different regions of the North Sea in the period 1947–1956". ICES, R. et P.-V., **143** (1): 9–11. Copenhague, 1957.

6) i Pilchard

Ahlstrom, E. H., & Kramer, D. "Sardine eggs and larvae and other fish larvae, Pacific coast, 1955". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **224**. Washington, 1957.
Cruz, J. A. M. "A sardinha do norte de Portugal. II. Caracteristicas etarias et de reproduçao". Publ. Inst. Dr. Aug. Nobre, **49**. Porto, 1955.
Cruz, J. A. M. "Sur la succession de générations dans la pêche à la sardine, au nord du Portugal, et ses possibles conséquences d'ordre économique". Publ. Inst. Dr. Aug. Nobre, **51**. Porto, 1955.
Cushing, D. H. "The number of pilchards in the Channel". MAFF, Fish. Invest., Ser. 2, **21** (5). London, 1957.
Dieuzeide, R., & Roland, J. "Etude biométrique de *Sardina pilchardus* Walb. et de *Sardinella aurita* C. V. capturées dans la Baie de Castiglione". Trav. Stat. Aquicult. et Pêche Castiglione, N. S., **8**: 109–225. Castiglione, 1957.
Dieuzeide, R., & Roland, J. "Observations relevées sur les sardines (*Sardina pilchardus* Walb.) de la Baie de Castiglione parasitées par *Peroderma cylindricum* Heller". Trav. Stat. Aquicult. et Pêche Castiglione, N. S., **8**: 227–49. Castiglione, 1957.
Gamulin, T., & Karlovac, J. "Données récentes concernant la densité des oeufs de sardine (*Sardina pilchardus* Walb.) sur une frayère de l'Adriatique moyenne". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 219–26. Rome, 1957.
Larrañeta, M. G. "Présence du parasite *Peroderma cylindricum* Heller sur la sardine de Castellon et d'Alicante". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 109–12. Rome, 1957.
Larrañeta, M. G., & López, J. "La croissance de la sardine (*Sardina pilchardus* Walb.) de la côte de Castellón". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 101–08. Rome, 1957.
Larrañeta, M. G., López, J., & Suau, P. "Composición de los desembarcos en la pesquería de sardina de Castellón". Invest. Pesqu., **9**: 3–25. Barcelona, 1957.
Matta, F. "La sardina (*Sardina pilchardus* Walb.) del Mare Tirreno. Annotazioni biometriche". Boll. Pesca, Piscicolt. et Idrobiol., **11** (2): 291–96. Roma, 1956.
Matta, F. "Sur la biométrie de la sardine (*Sardina pilchardus* Walb.) de la mer Tyrrhénienne". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 327–33. Rome, 1957.
Oliver, M. "Biologie de la sardine des Baléares". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 51–62. Rome, 1957.

Pinto, J. dos S. "Parasitic castration in males of *Sardina pilchardus* (Walb.) due to testicular infestation by the Coccidia *Eimeria sardinae* (Thélohan)". Rev. Fac. Ciênc., 2A, Ser. C, Ciênc. Natur., **5** (2): 209–28. Lisboa, 1957.

Pinto, J. dos S. "Deux cas de tumeurs sexuelles dans la sardina (*Sardina pilchardus* Walb.)". Rev. Fac. Ciênc., 2A, Ser. C, Ciênc. Natur., **5** (2): 257–60. Lisboa, 1957.

Pinto, J. dos S. "Échelle pour la caractérisation des phases évolutives de l'ovaire de sardine (*Sardina pilchardus* Walb.) en rapport avec l'histophysiologie de la gonade". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 393–411. Rome, 1957.

6) j Tunny and Mackerel

Acara, A. "Relation between the migration of *Sarda sarda* Bloch and prevailing temperature". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 193–96. Rome, 1957.

Akyüz, E. F., & Artüz, I. "Some observations on the biology of tuna (*Thunnus thynnus*)". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 93–99. Rome, 1957.

Bullis, H. R., & Mather, F. J. "Tunas of the genus *Thunnus* of the northern Carribbean". American Mus. Novit., **1765**. New York, 1956.

Cabo, F. L. "Notes sur la biologie et la pêche des thons". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 113–25. Rome, 1957.

Demir, M., & Arim, N. "Contribution to the biology of the mackerel (*Scomber scomber* L.)". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 135–39. Rome, 1957.

Doutre, M. "Déplacement des lieux de pêche de la flotille thonière basée à Dakar". Sci. et Pêche, Ser. B, **49**. Paris, 1957.

Figueras, A. "Datos sobre la edad y crecimiento de la albacora (*Germo alalunga*, Bonnaterre)". Invest. Pesqu., **9**: 27–31. Barcelona, 1957.

Graham, J. J. "Central North Pacific albacore surveys, May to November 1955". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **212**. Washington, 1957.

Hatanaka, M., *et al.* "Growth and food consumption in young mackerel, *Pneumatophorus japonicus* (Houttuyn)". Tohoku J. Agric. Res., **7** (4): 351–68. Sendai, 1957.

Hennemuth, R. C. "An analysis of methods of sampling to determine the size composition of commercial landings of yellowfin tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*)". Bull. Inter-American Trop. Tuna Commiss., **2** (5). La Jolla, Cal., 1957.

Ichikawa, R., *et al.* "Deposition of radiostrontium in the various tissues of jack mackerel, mackerel and tuna". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1143–50. Tokyo, 1956.

Iversen, E. S., & Yoshida, H. O. "Longline and troll fishing for tuna in the Central Equatorial Pacific, January 1955 to February 1956". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **203**. Washington, 1957.

King, J. E., & Wilson, P. T. "Studies on *Tilapia* as skipjack bait". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **225**. Washington, 1957.

Marty, J. J. "The tunny fishery in Norwegian waters". Rybn. Khoz., 1957 (11): 87–88. Moscow, 1957.

Massmann, W. H., & Pacheco, A. L. "Shad catches and water temperatures in Virginia". J. Wildl. Managem., **21** (3): 351–52. Lawrence, Kansas, 1957.

Mestres, J. P. "Estudio sobre el pancreas endocrino del bonito del Norte o albacora, *Germo alalunga*, Gml." Invest. Pesqu., **9**: 119–28. Barcelona, 1957.

Nümann, W. "Vorläufige Ergebnisse der Markierungsexperimente an Pelamiden (*Sarda sarda*) in türkischen Gewässern". Hidrobiologi, Ser. B, **2** (4): 157–66. Istanbul, 1955.

Nümann, W. "Die Pelamiden des Schwarzen Meeres, des Bosporus, der Marmara und der Dardanellen (*Sarda sarda*)". Hidrobiologi, Ser. B, **3** (2–3): 75–127. Istanbul, 1955.

Nümann, W. "Die Makrele (*Scomber scombrus*) des Schwarzen Meeres, des Bosporus und der Marmara". Hidrobiologi, Ser. B, **3** (4): 129–85. Istanbul, 1955.

Nümann, W. "Les résultats des expériences de marquage sur les pélamides et les maquereaux dans les eaux turques". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 69–78. Rome, 1957.

Nümann, W., *et al.* "Biologische Untersuchungen über die Stöcker des Bosporus, des Schwarzen Meeres und der Marmara (*Trachurus mediterraneous* Stdr.) und (*Trachurus trachurus* L.)". Hidrobiologi, Ser. B, **4** (1). Istanbul, 1956.

Powell, D. E. "North Pacific albacore tuna exploration by the M/V 'John N. Cobb' – 1956". Commerc. Fish. Rev., **19** (6): 1–9. Washington, 1957.

Sahut-Morel. "La pêche au thon tropical au large de Dakar d'une campagne à l'autre". Pêche Marit., **36** (953): 341–45. Paris, 1957.

Schaefer, M. B. "Report on the investigations of the Inter-American Tropical Tuna Commission for the year 1956". Ann. Rep. Inter-American Trop. Tuna Commiss. 1956: 33–70. La Jolla, Cal., 1957.

Tozawa, H., Tokue, Y., & Amano, K. "Studies on the radioactivity in certain pelagic fish – V. Confirmation and determination of radioactive elements in contaminated fishes caught in 1956 (part 1)". Bull. Japanese Soc. Sci. Fish., **23** (6): 335–41. Tokyo, 1957.

Tuggac, M. "On the biology of the *Scomber colias* Gmelin". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 145–59. Rome, 1957.

6) k Other Marine Pelagic Species

Arena, P., & Bolognari, A. "Il corpo glomerulare del genere *Engraulis*". Atti Soc. Peloritana Sci. Fisic., Mat. e Natur., **3** (3): 243–51. Messina, 1957.

Backus, R. H. "Notes on western North Atlantic sharks". Copeia, 1957 (3): 246. Baltimore, 1957.

Davies, D. H. "The South African pilchard (*Sardinops ocellata*) migration, 1950–55". Union South Africa Dept. Commerce & Industr., Invest. Rep. Div. Fish., **24**: 1–52. Pretoria, 1956.

Davies, D. H. "The South African pilchard (*Sardinops ocellata*). Size composition of the commercial catches, 1950–55". Union South Africa Dept. Commerce & Industr., Invest. Rep. Div. Fish., **26**. Pretoria, 1957.

Inoue, M. "The effect of wireless telephone on sardine purse seine fishery". Bull. Japanese Soc. Sci. Fish., **23** (1): 6–8. Tokyo, 1957.

Kemp, R. J. "Occurrences of the ocean sunfish, *Mola mola* (Linnaeus), in Texas". Copeia, 1957 (3): 250. Baltimore, 1957.

Kristensen, I. "Een massale stranding van de makreelgeep". Levende Natuur, **59** (3): 59–64. Amsterdam, 1956.

Kux, Z., & Libosvarsky, J. "Zur Verbreitung und Rassenzugehörigkeit der europäischen Hundsfische (*Umbra krameri* Walbaum 1792 = *lacustris* Gross 1794)". Zool. Listy, **20**: 215–24. Brno, 1957.

Marr, J. C. "The subpopulation problem in the Pacific sardine, *Sardinops caerulea*". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 108–25. Washington, 1957.

Nicolae, I., & Cautis, I. "Observations sur le comportement du chinchard (*Trachurus trachurus mediterraneus* Stdr.) au littoral roumain de la Mer Noire durant le période 1953–1955". Anal. Inst. Cercetari Pisc., **1**: 207–25. Bucuresti, 1956.

Nishimura, S. "Some considerations regarding the amount of foods daily taken by an early postlarva of sardine". Ann. Rep. Japan Sea Reg. Fish. Res. Lab., **3**: 77–84. Niigata, 1957.

Pora, E. A., *et al.* "La nourriture du chinchard (*Trachurus trachurus mediterraneus* Stdr.) durant une saison de pêche (mai-octobre 1953)". Anal. Inst. Cercetari Pisc., **1**: 187–206. Bucuresti, 1956.

Srivastava, P. N. "On the air-bladder of *Chirocentrus dorab* (Forsk.), and the relationship of family Chirocentridae with Clupeidae". Zool. Anz., **156** (11–12): 284–88. Leipzig, 1956.

Walburg, C. H. "Neuse River shad investigations, 1953". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **206**. Washington, 1957.

Wood, F. G. "Southern extension of the known range of the basking shark, *Cetorhinus maximus* (Gunnerus)". Copeia, 1957 (2): 153. Baltimore, 1957.

6) l Salmon and Trout

Adelman, W. J., & Haskell, D. C. "The excitability of the brown trout". Physiol. Comp. et Oecol., **4** (4): 375–87. Amsterdam, 1957.

Ahlstrom, E. H. "A review of recent studies of subpopulations of Pacific fishes". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 44–73. Washington, 1957.

Alderdice, D. F., & Brett, J. R. "Some effects of Kraft mill effluent on young Pacific salmon". J. Fish. Res. Board Canada, **14** (5): 783–95. Ottawa, 1957.

Alderdice, D. F., & Brett, J. R. "Toxicity of sodium arsenite to young chum salmon". Fish. Res. Board Canada, Progr. Rep. Pacific Coast Stat., **108**: 27–29. Ottawa, 1957.

Anon. "Investigation and management of the Atlantic salmon". Trade News, **9** (12): 3–18. Ottawa, 1957.

Black, E. C. "Alterations in the blood level of lactic acid in certain salmonoid fishes following muscular activity. II. Lake trout, *Salvelinus namaycush*". J. Fish. Res. Board Canada, **14** (4): 645–49. Ottawa, 1957.

Black, E. C. "Alterations in the blood level of lactic acid in certain salmonoid fishes following muscular activity. III. Sockeye salmon, *Oncorhynchus nerka*". J. Fish. Res. Board Canada, **14** (6): 807–14. Ottawa, 1957.

Black, E. C., & Barrett, I. "Increase in levels of lactic acid in the blood of cutthroat and steelhead trout following handling and live transportation". Canadian Fish Cult., **20**: 13–24. Ottawa, 1957.

Bridges, C. D. B. "The visual pigments of the rainbow trout (*Salmo irideus*)". J. Physiol., **134** (3): 620–29. London, 1956.

Clutter, R. I., & Whitesel, L. E. "Collection and interpretation of sockeye salmon scales". Bull. Internat. Pacific Salmon Fish. Commiss., **9**. New Westminster, B. C., 1956.

Coates, J. A., Ellis, C. H., & Schwab, R. L. "Brine shrimp nauplii (*Artemia gracilis*) as food for juvenile pink salmon". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 67–72. Washington, 1957.

Cope, O. B. "Races of cutthroat trout in Yellowstone Lake". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 74–84. Washington, 1957.

Donaldson, L. R., Hansler, D. D., & Buckridge, T. N. "Interracial hybridization of cutthroat trout, *Salmo clarkii*, and its use in fisheries management". Trans. American Fish. Soc., **86**: 350–60. St. Paul, Minnesota, 1957.

Downing, K. M., & Merkens, J. C. "The influence of dissolved-oxygen concentration on the toxicity of un-ionized ammonia to rainbow trout (*Salmo gairdnerii* Richardson)". Ann. Appl. Biol., **43** (2): 243–46. Cambridge, 1955.

Ellis, R. J., & Gowing, H. "Relationship between food supply and condition of wild brown trout, *Salmo trutta* Linnaeus, in a Michigan stream". Limnol. & Oceanogr., **2** (4): 299–308. Baltimore, 1957.

Fields, P. E. "Guiding migrant salmon". Sci. Monthly, **85** (1): 10–22. Washington, 1957.

Fontaine, M., & Olivereau, M. "The anterior interrenal (gland) and smolt-stage formation in *Salmo salar*". J. Physiol., **49**: 174–76. Paris, 1957.

Hallock, R. J., Fry, D. H., & Lafaunce, D. A. "The use of wire fyke traps to estimate the runs of adult salmon and steelhead in the Sacramento River". California Fish & Game, **43** (4): 271–98. Sacramento, 1957.

Herbert, D. W. M., & Downing, K. M. "A further study of the toxicity of potassium cyanide to rainbow trout (*Salmo gairdnerii* Richardson)". Ann. Appl. Biol., **43** (2): 237–42. Cambridge, 1955.

Herbert, D. W. M., *et al.* "Toxicity of synthetic detergents to rainbow trout". Water & Waste Treatment J., 1957 (September/October). London, 1957.

Hoar, W. S., Keenleyside, M. H. A., & Goodall, R. G. "Reactions of juvenile Pacific salmon to light". J. Fish. Res. Board Canada, **14** (6): 815–30. Ottawa, 1957.

Hoshina, T. "Further observations on the causative bacteria of the epidemic disease like furunculosis of rainbow-trout". J. Tokyo Univ. Fish., **43** (1): 59–66. Tokyo, 1957.

Hoshina, T., & Chiba, T. "On the bacteriostatic power of malachite green against the causative bacteria of vibrio-disease of rainbow-trout". Bull. Japanese Soc. Sci. Fish., **23** (4): 199–201. Tokyo, 1957.

Hoshina, T., Kunimine, I., & Takahashi, T. "Preliminary studies on control of the vibrio-disease of rainbow-trout". Bull. Japanese Soc. Sci. Fish., **23** (5): 241–44. Tokyo, 1957.

Houston, A. H. "Responses of juvenile chum, pink, and coho salmon to sharp sea-water gradients". Canadian J. Zool., **35** (3): 371–83. Ottawa, 1957.

Idler, D. R., *et al.* "Olfactory perception in migrating salmon. I. L-serine, a salmon repellent in mammalian skin". J. Gen. Physiol., **39** (6): 889–92. Baltimore, 1956.

Kobayashi, S., & Hirata, H. "Effects of X-irradiation upon rainbow trout (*Salmo irideus*). I. Influence on the feeding activity in rainbow trout fry". Bull. Fac. Fish. Hokkaido Univ., **8** (1): 23–35. Hakodate, 1957.

Kotov, V. L. "Preservation and regulation of the Pacific salmon industry". Rybn. Khoz., 1957 (12): 55–58. Moscow, 1957.

Lennon, R. E. "Observations on wild, long-jaw rainbow trout". Progr. Fish-Cult., **19** (4): 179–81. Washington, 1957.

LINDROTH, A. "A study of the whitefish (*Coregonus*) of the Sundsvall Bay district". Rep. Inst. Freshw. Res. Drottningholm, **38**: 70–108. Lund, 1957.

LINDROTH, A. "Baltic salmon fluctuations: a reply". Rep. Inst. Freshw. Res. Drottningholm, **38**: 109–30. Lund, 1957.

MEKHANIK, F. J. "The influence of O_2-concentration on the growth and N_2-exchange of young rainbow trout". Rybn. Khoz., 1957 (7): 74–75. Moscow, 1957.

MERKEL, T. J. "Food habits of the king salmon, *Oncorhynchus tshawytscha* (Walbaum), in the vicinity of San Francisco, California". California Fish & Game, **43** (4): 249–70. Sacramento, 1957.

MILLER, R. B. "Permanence and size of home territory in stream-dwelling cutthroat trout". J. Fish. Res. Board Canada, **14** (5): 687–92. Ottawa, 1957.

MIYAGUCHI, K., & ISHIDA, T. "On the observation of scale pattern of pink salmon". Bull. Hokkaido Reg. Fish. Res. Lab., **16**: 49–55. Hokkaido, 1957.

NILSSON, N.-A. "On the feeding habits of trout in a stream of northern Sweden". Rep. Inst. Freshw. Res. Drottningholm, **38**: 154–66. Lund, 1957.

ORAV, V. I. "Reasons for the cessation of catching salmon in the River Daugava". Rybn. Khoz., 1956 (10): 57–58. Moscow, 1956.

PHILLIPS, A. M., & BALZER, G. C. "The nutrition of trout. V. Ingredients for trout diets". Progr. Fish-Cult., **19** (4): 158–67. Washington, 1957.

REES, W. H. "The vertical and horizontal distribution of seaward migrant salmon in the forebay of Baker Dam". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 5–17. Washington, 1957.

REGENTHAL, A. F. "Downstream migrant salmon survival in free fall from a ski-jump spillway". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 19–24. Washington, 1957.

ROBERTSON, O. H., & PINFRET, A. P. "Maturation of the infantile testes in rainbow trout (*Salmo gairdnerii*) produced by salmon pituitary gonadotrophins administered in cholesterol pellets". Endocrinol., **60** (4): 559–62. Glendale, Calif., 1957.

RUNNSTRÖM, S. "Migration, age and growth of the brown trout (*Salmo trutta* L.) in Lake Rensjön". Rep. Inst. Freshw. Res. Drottningholm, **38**: 194–246. Lund, 1957.

SASHBY, K. R. "The effect of steroid hormones on the brown trout (*Salmo trutta* L.) during the period of gonadal differentiation". J. Embryol. & Exper. Morphol., **5** (3): 225–49. Oxford, 1957.

SCHLUMBERGER, H. G., & KATZ, M. "Odontogenic tumors of salmon". Cancer Res., **16** (4): 369–70. Baltimore, 1956.

SEGUIN, R. L. "Management, fishing results and growth of speckled trout (*Salvelinus fontinalis*) in Baldwin Pond, Stanstead County, Que." Canadian Fish Cult., **20**: 29–37. Ottawa, 1957.

SHIRKOVA, A. P. "On the biological heterogeneity of *Coregonus lavaretus maraenoides* Poljakow in connection with its introduction into other water reservoirs". Zool. Zhurn., **36** (6): 851–53. Moscow, 1957.

SMIRNOV, A. I. "Some problems of the biological basis for acclimatization of Pacific salmon". Rybn. Khoz., 1956 (10): 54–56. Moscow, 1956.

SMITH, M. W. "Comparative survival and growth of tagged and untagged brook trout". Canadian Fish Cult., **20**: 1–6. Ottawa, 1957.

SMITH, M. W. "Lea's hydrostatic tag on brook trout and Atlantic salmon smolts". Canadian Fish Cult., **20**: 39–44. Ottawa, 1957.

SMITH, R. T., & QUISTORFF, E. "Survival capacity of spermatozoa of the chinook salmon and steelhead trout". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 73–76. Washington, 1957.

SMITH, S. B. "Survival and growth of wild and hatchery rainbow trout (*Salmo gairdnerii*) in Corbett Lake, B. C." Canadian Fish Cult., **20**: 7–12. Ottawa, 1957.

SMITH, S. H. "Evolution and distribution of the coregonids". J. Fish. Res. Board Canada, **14** (4): 599–604. Ottawa, 1957.

SNIESZKO, S. F. "Disease resistant and susceptible populations of brook trout (*Salvelinus fontinalis*)". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 126–28. Washington, 1957.

SVÄRDSON, G. "The coregonid problem. VI. The Palearctic species and their intergrades". Rep. Inst. Freshw. Res. Drottningholm, **38**: 267–356. Lund, 1957.

TAIT, J. S. "Nitrogen and argon in salmonoid swimbladders". Canadian J. Zool., **34**: 58–62. Ottawa, 1956.

THOMAS, J. D. "Occurrence of *Crepidostomum metoecus* (Braun, 1900) in Britain". Nature, **180** (4600): 1492. London, 1957.

VERNON, E. H. "Morphometric comparison of three races of kokanee (*Oncorhynchus nerka*) within a large British Columbia lake". J. Fish. Res. Board Canada, **14** (4): 573–98. Ottawa, 1957.

VIBERT, R. "Du rendement comparé des divers modes de repeuplements en truites et saumons". Bull. Centre Étud. et Rech. Sci. Biarritz, **1** (3): 321–42. Biarritz, 1957.

VORBRODT, K. "Histological changes in the muscles of sea trout embryos (*Salmo trutta* L.) induced by the temperature of +30° C." Folia Biol., **5** (3): 175–93. Poland, 1957.

WILIMOVSKY, N. J., & FREIHOFER, W. O. "Guide to literature on systematic biology of Pacific salmon". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **209**. Washington, 1957.

WOHLSCHAG, D. E. "Differences in metabolic rates of migratory and resident freshwater forms of an Arctic whitefish". Ecology, **38** (3): 502–10. Durham, N. C., 1957.

YUKI, R. "Blood cell constituents in fish. I. Peroxidase staining of the leucocytes in rainbow trout (*Salmo irideus*)". Bull. Fac. Fish. Hokkaido Univ., **8** (1): 36–44. Hakodate, 1957.

6) m Eels

DEELDER, C. L. "On the growth of eels in the IJsselmer". ICES, J. Cons., **23** (1): 83–88. Copenhague, 1957.

FLEMMING, H. "Schwimmblasenentzündung eines Aales *Anguilla anguilla* (L.)". Deutsche Fisch.-Zeit., 1954 (6): 158–59. Radebeul, 1954.

GODFREY, H. "Feeding of eels in four New Brunswick salmon streams". Fish. Res. Board Canada, Progr. Rep. Atlantic Coast Stat., **67**: 19–22. St. Andrews, 1957.

GOLLUB, H. "Über einige Möglichkeiten zur Intensivierung der Aalwirtschaft". Deutsche Fisch.-Zeit., 1955 (4): 22–26. Radebeul, 1955.

GOLLUB, H. "Intensivierung des Aalbesatzes durch Zusammenschluss zu Aalbesatzgemeinschaften". Deutsche Fisch.-Zeit., 1957 (9): 262–64. Radebeul, 1957.

KASAHARA, S. "Marking experiment on the glass-eel of *Anguilla japonica*". Aquiculture, **3**: 43. Japan, 1955.

NAKAMURA, N. "Some examples of large male eels". Aquiculture, **3**: 56–57. Japan, 1955.

OLIVEREAU, M. "Radiothyroidectomie chez l'anguille (*Anguilla anguilla* L.)". Arch. Anat. Microscop. et Morphol. Expér., **46** (1): 39–59. Paris, 1957.

6) n Other Freshwater Species

ALM, G. "The yield of the pike and perch fisheries along the Baltic coasts of Sweden during the years 1914–1955". Rep. Inst. Freshw. Res. Drottningholm, **38**: 5–69. Lund, 1957.

FRANCA, P. "Contribuiçao para o conhecimento dos Serranidae de Angola". Trab. Miss. Biol. Marit., 1955 (12): 7–45. Lisboa, 1957.

6) o General

ALBUQUERQUE, R. M. "Peixes de Portugal e ilhas adjacentes. Chaves para a sua determinação". Portugaliae Acta Biol., Ser. B, **5**: 1–1164. Lisboa, 1956.

D'ANCONA, U. "Morphogénèse et différenciation sexuelle chez les poissons téléostéens". Bull. Soc. Zool. France, **81** (4): 219–29. Paris, 1957.

ANON. "Conservation and reproduction of fish resources – the most important national industrial problem". Rybn. Khoz., 1956 (11): 1–5. Moscow, 1956.

ARITA, Y. "An anatomical and histological study of the swimbladder". Igaku kenkyu, **26** (6): 176–203. Kyushu, 1956.

ARMSTRONG, P. B. "Motility in developing teleost embryos". Biol. Bull., **113** (2): 325. Lancaster, Pa., 1957.

BACKUS, R. H. "The fishes of Labrador". Bull. American Mus. Natur. Hist., **113** (4). New York, 1957.

BARADUC, M. M. "Influence of thyroxine on chloride-ion exchange in rainbow trout (*Salmo gairdneri*)". CR Soc. Biol., **151**: 303–05. Paris, 1957.

BARDACH, J. E., & BJORKLUND, R. G. "The temperature sensitivity of some American freshwater fishes". American Natur., **91** (859): 233–51. Lancaster, Pa., 1957.

BAS, C. "La géographie du fond et l'état actuel de la pêche des espèces d'intérêt industriel". Gen. Fish. Counc. Mediterranean, Proc. & Techn. Pap., **4**: 235–41. Rome, 1957.

Bergeron, J. A. "A histophysiological study of osmotic regulation in the euryhaline teleost *Fundulus heteroclitus*". Dissert. Abstr., **16** (11): 2192–93. Ann Arbor, Mich., 1956.

Bidwell, K. W. E., & Foreman, E. E. "Distribution of strontium-90 in pond weed and fish". Nature, **180** (4596): 1195–96. London, 1957.

Bigelow, H. B., & Schroeder, W. C. "A study of the sharks of the suborder Squaloidea". Bull. Mus. Comp. Zool. Harvard Univ., **117** (1). Cambridge, Mass., 1957.

Bopp, P. "Verhaltensstudien an Meergrundeln (Gobiidae) in Gefangenschaft". Physiol. Comp. et Oecol., **4** (3): 247–69. Amsterdam, 1957.

Borisov, P. G. "The behaviour of fishes under the influence of artificial light". Proc. Conf. Behaviour of Fish & on Locating of its Commercial Concentrations: 121–43. Moscow, 1955.

Briggs, J. C. "A new genus and two new species of eastern Atlantic clingfishes". Copeia, 1957 (3): 204–12. Baltimore, 1957.

Brown, M. E. "The physiology of fishes. Vol. 2. Behaviour". Academic Press Inc., New York, 1957.

Bullock, W. L. "The Acanthocephalan parasites of the fishes of the Texas coast". Publ. Inst. Mar. Sci., **4** (2): 278–83. Port Aransas, Texas, 1957.

Burley, R. W., & Solomons, C. C. "The amino-acid composition of fish-scale proteins". South African Industr. Chem., **11**: 154–57. South Africa, 1957.

Burnstock, G. "A 'window' technique for observing fish viscera *in vivo*". Nature, **180** (4600): 1491. London, 1957.

Buznikov, G. A. "On the physiology of the glands of embryo hatching in Teleostea". Zhurn. Obshch. Biol., **18** (5): 350–59. Moscow, 1957.

Chapman, D. W. "An improved portable tattooing device". Progr. Fish-Cult., **19** (4): 182–84. Washington, 1957.

Denton, E. J., & Warren, F. J. "The photosensitive pigments in the retinae of deep-sea fish". J. Mar. Biol. Assoc., **36** (3): 651–62. Cambridge, 1957.

deWitt, J. W. "Mortality of aquatic insects and fishes caused by use of latex tubing in experimental apparatus". Science, **126** (3278): 840. Lancaster, Pa., 1957.

Doudoroff, P. "Water quality requirements of fishes and effects of toxic substances". Physiol. Fishes, **2**: 403–30. New York, 1957.

Downing, K. M., & Merkens, J. C. "The influence of temperature on the survival of several species of fish in low tensions of dissolved oxygen". Ann. Appl. Biol., **45**: 261–67. Cambridge, 1957.

Ege, V. "Paralepididae. II. (Macroparalepis). Taxonomy, ontogeny, phylogeny and distribution". Dana-Rep., **43**. Copenhagen, 1957.

Fox, D. L. "Pigments of fishes". Physiol. Fishes, **2**: 367–85. New York, 1957.

Frick, H. C. "The optimum level of fisheries exploitation"'. J. Fish. Res. Board Canada, **14** (5): 683–86. Ottawa, 1957.

Gibbs, R. H. "Cyprinid fishes of the subgenus *Cyprinella* of *Notropis*. I. Systematic status of the subgenus *Cyprinella*, with a key to the species exclusive of the *lutrensis-ornatus* complex". Copeia, 1957 (3): 185–95. Baltimore, 1957.

Gibbs, R. H. "A taxonomic analysis of *Myctophum affine* and *M. nitidulum*, two lanternfishes previously synonymized, in the western North Atlantic". Deep-Sea Res., **4** (4): 230–37. London & New York, 1957.

Giichi, Y. "Radioactivity in fish near Christmas Island after test explosion of atomic bomb. Studies on the radioactive marine organisms (especially *Katsuwonus vagans*) caused by nuclear detonation". J. Fac. Fish. Pref. Univ. Mie, **2** (2): 43–96. Otanimachi, Tsu, 1956.

Gilbert, P. W., & Wood, F. G. "Method of anesthetizing large sharks and rays safely and rapidly". Science, **126** (3266): 212–13. Washington, 1957.

Grey, M. "Fishes found below a depth of 2,000 metres". Internat. Union Biol. Sci., Ser. B, **16**: 57–61. Naples, 1954.

Harada, Y. "Blood sugar contents of marine fishes". Igaku to Seibutsugaku, **30**: 205–07. Tokyo, 1954.

Harrington, R. W. "Sexual photoperiodicity of the cyprinid fish *Notropus bifrenatus* (Cope), in relation to the phases of its annual reproductive cycle". J. Exper. Zool., **135** (3): 529–53. Philadelphia, 1957.

Hibiya, T., & Yagi, T. "Effects of fission materials upon the development of aquatic animals". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1219–24. Tokyo, 1956.

Hiyama, Y. "Studies on the processes of contamination of fish by the fission product". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1119. Tokyo, 1956.

Hiyama, Y., & Ichikawa, R. "Up-take of strontium by marine fish from the environment (I)". Rec. Oceanogr. Works Japan, **3** (1): 78–84. Tokyo, 1957.

Hiyama, Y., & Yasuda, F. "The methods of utilization of plankton by fishes". Rec. Oceanogr. Works Japan, Spec. No. Oceanogr. Res. Proj. Japanese Nation. Commiss. UNESCO: 67–70. Tokyo, 1957.

Hubbs, C. L. "The distribution of Macrourids". Internat. Union Biol. Sci., Ser. B, **16**: 62–64. Naples, 1954.

Humm, D. G., Clark, E. E., & Humm, J. H. "Transplantation of melanomas from platyfish-swordfish hybrids into embryos of swordtails, platyfish and their hybrids". J. Exper. Biol., **34** (4): 518–28. Cambridge, 1957.

Ichikawa, R., & Hiyama, Y. "Some notes on the radioassay of contaminated fishes". Res. on the effects and influences of the nuclear bomb test esplosions, Japanese Soc. Prom. Sci.: 883–88. Tokyo, 1956.

Itazawa, Y. "Gas content of the blood in response to that of medium water in fish". Bull. Japanese Soc. Sci. Fish., **23** (2): 71–80. Tokyo, 1957.

John, K. R. "Observations on the behaviour of blind and blinded fishes". Copeia, 1957 (2): 123–32. Baltimore, 1957.

Kanoh, Y., & Yamamoto, T. S. "Removal of the membrane of the dog salmon egg by means of proteolytic enzymes". Bull. Japanese Soc. Sci. Fish., **23** (3): 166–72. Tokyo, 1957.

Kanwisher, J., & Ebeling, A. "Composition of the swim-bladder gas in bathypelagic fishes". Deep-Sea Res., **4** (3): 211–17. London & New York, 1957.

Kessler, R., & Luther, W. "Die Wirkung der Röntgenstrahlen auf den Hoden und die sekundären Geschlechtsmerkmale von *Lebistes reticulatus* Peters". Zeitschr. Vergl. Physiol., **40** (5): 492–528. Berlin, 1957.

Krayukhin, B. V. "Chronic fistula method and its use in studying the physiology of the digestion of fish". Izvest. Akad. Nauk SSSR, 1956: 49. Moscow, 1956.

Kulikova, E. B. "Growth of deep-sea fishes". Trudy Inst. Okeanol., **20**: 347. Moscow, 1957.

Kusaka, T. "Experiments to see the different effects of net on driving several species of fish". Bull. Japanese Soc. Sci. Fish., **23** (1): 1–5. Tokyo, 1957.

Lemanova, N. A. "Analysis of the occurrence of sterility in males of the hybrid ludoga (*Coregonus lavaretus ludoga* Pol.) × ripus (*Coregonus infr. lodogesis* Prav.)". Doklady Akad. Nauk SSSR, **105** (1): 160–62. Moscow, 1955.

Leonte, V. "Contributions à l'étude de la biologie des esturgeons marins des eaux de la R. P. Roumaine". Anal. Inst. Cercetari Pisc., **1**: 167–85. Bucuresti, 1956.

Liston, J. "The occurrence and distribution of bacterial types on flatfish". J. Gen. Microbiol., **16**: 205–16. London, 1957.

Lyall, A. H. "Cone arrangements in teleost retinae". Quart. J. Microscop. Soc., **98** (2): 189–201. Oxford, 1957.

Manfredi, P. "Vita dei pesci". Milano, 1956.

Manter, H. W. "Host specificity and other host relationships among the digenetic trematodes of marine fishes". Premier Symposium sur la spécificité parasitaire des parasites de Vertébrés, Union Internat. Sci. Biol., Ser. B, **32**: 185–98. Paris, 1957.

Margetts, A. R. "The length-girth relationships in whiting and cod and their application to mesh selection". ICES, J. Cons., **23** (1): 64–71. Copenhague, 1957.

Margetts, A. R. "The North Sea has great natural resources". Fishing News, 1957 (2324): 8. London, 1957.

Marr, J. C. "The problem of defining and recognizing subpopulations of fishes". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 1–6. Washington, 1957.

Massmann, W. H. "New and recent records for fishes in Chesapeake Bay". Copeia, 1957 (2): 156. Baltimore, 1957.

Mather, F. J., & Gibbs, R. H. "Distributional records of fishes from waters off New England and the middle Atlantic states". Copeia, 1957 (3): 242–45. Baltimore, 1957.

Matty, A. J. "Thyroidectomy and its effect upon oxygen consumption of a teleost fish, *Pseudoscarus guacamaia*". J. Endocrinol., **15** (1): 1–8. London, 1957.

Mead, G. W. "On the bramid fishes of the Gulf of Mexico". Zoologica, **42** (2): 51–61. New York, 1957.

Merkens, J. C., & Downing, K. M. "The effect of tension of dissolved oxygen on the toxicity of un-ionized ammonia to several species of fish". Ann. Appl. Biol., **45** (3): 521–27. Cambridge, 1957.

Miller, R. B. "Have the genetic patterns of fishes been altered by introductions or by selective fishing?" J. Fish. Res. Board Canada, **14** (6): 797–806. Ottawa, 1957.

Miyake, I. "The response of tuna and other fish to electrical stimuli". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **223**. Washington, 1957.

Motais, R. "Sur l'absorption de la lumière par le cristallin de quelques poissons de grande profondeur". Bull. Inst. Océanogr., **1094**. Monaco, 1957.

Nemoto, C. M. "Experiments with methods for air transport of live fish". Progr. Fish-Cult., **19** (4): 147–57. Washington, 1957.

Nickel, E. "Vergleichend experimentelle Untersuchungen über den Stoffwechsel des isolierten lebenden Kiemengewebes von Regenbogenforelle (*Trutta iridea* W. Gibb.) und Döbel (*Squalius cephalus* L.)". Zeitschr. Vergl. Physiol., **40** (1): 42–64. Berlin, 1957.

Nicol, J. A. C. "Observations on photophores and luminescence in the teleost *Porichthys*". Quart. J. Microscop. Sci., **98** (2): 179–88. Oxford, 1957.

Nümann, W., & Denizci, R. "Orientierende Untersuchungen an Meerbarben (*Mullus barbatus*, *Mullus surmuletus*, *Mulloidichthys auriflamma*), insbesondere Berechnungen über die Notwendigkeit einer Einführung von fischereilichen Schonmassnahmen in den türkischen Gewässern". Hidrobiologi, Ser. B, **3** (1): 35–56. Istanbul, 1955.

Nybelin, O. "Sur la distribution géographique et bathymétrique des Brotulidés trouvés au-dessous de 2,000 mètres de profondeur". Internat. Union Biol. Sci., Ser. B, **16**: 65–71. Naples, 1954.

Obo, F., *et al.* "Radioactivity of fish. II". Igaku to Seibutsugaku, **34**: 255–58. Japan, 1955.

Obo, F., *et al.* "Radioactivity of fishes. IV. Analysis of ash from radioactive fishes". Igaku to Seibutsugaku, **36**: 32–35. Tokyo, 1955.

Oren, O. H. "Changes in temperature of the eastern Mediterranean Sea in relation to the catch of the Israel trawl fishery during the years 1954–55 and 1955–56". Bull. Inst. Océanogr., **1102**. Monaco, 1957.

Otis, L. S., Cerf, J. A., & Thomas, G. J. "Conditioned inhibition of respiration and heart rate in the goldfish". Science, **126** (3267): 263–64. Lancaster, Pa., 1957.

Parenzan, P. "Un reperto interessante nel Mare di Taranto – Prima cattura di *Chlopsis bicolor* Raf. (Pisces)". Boll. Pesca, Piscicolt. e Idrobiol., **11** (2): 297–99. Roma, 1956.

Priwolujew, I. "Das Verhalten der Fische im elektrischen Feld". Deutsche Fisch.-Zeit., 1954 (4): 124–25. Radebeul, 1954.

Reichenbach-Klinke, H. H. "Vorläufige Mitteilung über die Parasiten der Fische des Golfs von Neapel". Pubbl. Staz. Zool. Napoli, **30** (1): 115–26. Napoli, 1957.

Reid, G. K., Inglis, A., & Hoese, H. D. "Summer foods of some fish species in East Bay, Texas". Southwestern Natur., **1** (3): 100–04. USA, 1956.

Remotti, E., & Rizzo, L. "Riduzione fisiologica del fegato e reazione tumorale in *Gambusia holbrooki* Grd." Atti Accad. Lig. Sci. e Lett., **13** (1): 297–302. Genova, 1957.

Remotti, E., & Rizzo, L. "Fattori nervosi nella distribuzione di tumori da *Saprolegnia* in *Gambusia holbrooki* Grd." Atti Accad. Lig. Sci. e Lett., **13** (1): 303–07. Genova, 1957.

Rigdon, R. H., & Hendricks, J. W. "Myxosporidia in fishes of Gulf of Mexico". J. Parasitol., **41**: 511–18. Lancaster, Pa., 1955.

Ritzhaupt, H. "Zur Frage der Beziehungen von Wassertemperatur zum Fischvorkommen". Deutsche Fisch.-Zeit., 1957 (8): 225–31. Radebeul, 1957.

Robins, C. R. "Effects of storms on the shallow-water fish fauna of southern Florida with new records of fishes from Florida". Bull. Mar. Sci. Gulf & Caribbean, **7** (3): 266–75. Coral Gables, Fla., 1957.

Rosenthal, H. L. "Uptake of calcium-45 and strontium-90 from water by fresh-water fishes". Science, **126**: 699–700. Lancaster, Pa., 1957.

Royce, W. F. "Statistical comparison of morphological data". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 7–28. Washington, 1957.

Ryzhkov, L. P. "Changes in gas metabolism of small fish under influence of radioactive substances". Izvest. Akad. Nauk Armyan. SSR, Biol. i Sel'skokhoz. Nauki, **10** (3): 101–04. 1957.

Saeki, A., & Sano, K. "Absorption and metabolism of fission products in goldfish". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1105–17. Tokyo, 1956.

Scattergood, L. W., & Coffin, G. W. "Records of some Gulf of Maine fishes". Copeia, 1957 (2): 155. Baltimore, 1957.

Schaefer, M. B. "Some considerations of population dynamics and economics in relation to the management of the commercial marine fisheries". J. Fish. Res. Board Canada, **14** (5): 669–81. Ottawa, 1957.

Schemainda, R. "Über den Einfluss der meteorologisch-hydrographischen Bedingungen auf die Fischerei in den Gewässern um Grönland". Deutsche Fisch.-Zeit., 1957 (4): 98–105. Radebeul, 1957.

Scholander, P. F. "Observations on the gas gland in living fish". J. Cell. & Comp. Physiol., **48** (3): 523–28. Philadelphia, 1956.

Scholander, P. F., & van Dam, L. "Micro gasometric determination of oxygen in fish blood". J. Cell. & Comp. Physiol., **48** (3): 529–32. Philadelphia, 1956.

Schroll, F. "Zur Ernährungsphysiologie der Ammocoeteslarven der Cyclostomen". Zool. Anzeig., **159** (3–4): 75–78. Leipzig, 1957.

Sellaeg, J. "The problems of protection of fish stocks in relation to the Norwegian fisheries". Norwegian Fish. News, **4** (3): 20–21. Bergen, 1957.

Shamardina, I. P. "Changes in the intensity of respiration of fish in the course of their development". Doklady Akad. Nauk SSSR, **98** (4): 689–92. Moscow, 1954.

Shelbourne, J. E. "Site of chloride regulation in marine fish larvae". Nature, **180** (4592): 920. London, 1957.

Slastenenko, E. P. "A list of natural fish hybrids of the world". Hidrobiologi, Ser. B, **4** (2–3): 74–97. Istanbul, 1957.

Smith, J. L. B. "Swordfish, marlin and sailfish in South and East Africa". Ichthyol. Bull. Rhodes Univ., **2**. Grahamstown, 1956.

Spärck, R. "Origin and distribution of the deep sea bottom fauna. Summary of the colloquium". Internat. Union Biol. Sci., Ser. B, **16**: 89–90. Naples, 1954.

Spurway, H. "Hermaphroditism with self-fertilization, and the monthly extrusion of unfertilized eggs, in the viviparous fish *Lebistes reticulatus*". Nature, **180** (4597): 1248–51. London, 1957.

Starr, T. J., & Fosberg, W. "Filter paper electrophoresis of serum proteins from sharks". Copeia, 1957 (4): 292–95. Baltimore, 1957.

Stoll, L. M. "Changes in the cytological structure of the adenohypophysis and gonads in juvenile *Bathygobius soporator* after pituitary implantation". Zoologica, **42** (3,9). New York, 1957.

Stroganov, N. S. "Physiological adaptability of fish to the temperature of a given medium". Izvest. Akad. Nauk SSSR, 1956: 151. Moscow, 1956.

Subklew, H. J. "Veränderungen in der Fischfauna des Greifswalder Boddens in den vergangenen 100 Jahren". Deutsche Fisch.-Zeit., 1957 (7): 193–96. Radebeul, 1957.

Suyehiro, Y., *et al.* "Transmission and metabolism of strontium 90 in aquatic animals". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1135–42. Tokyo, 1956.

Suyehiro, Y., *et al.* "Effects of radioactive materials upon blood-pictures of fish". Res. on the effects and influences of the nuclear bomb test explosions, Japanese Soc. Prom. Sci.: 1231–32. Tokyo, 1956.

Takemura, Y. "Change in size of the ova of the mackerel in formalin solution relevant to determination of the maturity". Bull. Tokai Reg. Fish. Res. Lab., **15**: 29–38. Tokyo, 1957.

Tamura, T., Mitarai, G., & Sugita, Y. "The lowest intensity of illumination to produce the maximum cone potential in the fish retina and its ecological meaning". Bull. Japanese Soc. Sci. Fish., **23** (2): 86–91. Tokyo, 1957.

Thomopoulos, A. "Sur la ligne latérale des téléostéens. I. *Coecula* (*Sphagebranchus*) *imberbis* De La Roche et *Ophidion barbatum* Klein à l'éclosion". Bull. Soc. Zool. France, **82** (1): 102–07. Paris, 1957.

Thomopoulos, A., & Bauchot, R. "Sur *Cottus bubalis* Euphrasen. I. Reproduction en aquarium et développement embryonnaire". Bull. Soc. Zool. France, **82** (1): 120–26. Paris, 1957.

Tuge, H. "Studies of the conditioned reflex in the lower vertebrates. IV. Differentiation in goldfish". Ann. Rep. Japan Sea Reg. Fish. Res. Lab., **3**: 23–33. Niigata, 1957.

Tuge, H., Kanayama, Y., & Yamagishi, H. "Studies of the conditioned reflex in lower vertebrates. V. Respiratory defensive conditioned reflex in carp". Ann. Rep. Japan Sea Reg. Fish. Res. Lab., **3**: 35–42. Niigata, 1957.

Valerien, J. "L'anhydrase carbonique et la production des gaz de la vessie natatoire de *Serranus cabrilla* (L.) et *S. scriba* (L.)". Vie et Milieu, **8** (1): 23–57. Paris, 1957.

Vargas, F. F., & Concha, B. J. "Fisiologia de la glandulas adrenales en el teleosteo *Sicyases sanguineus*". Invest. Zool. Chilenas, **3** (5/7): 88–95. Santiago, 1957.
Velankar, N. K., & Govindan, T. K. "The free a-amino acid nitrogen content of the skeletal muscle of some marine fishes and invertebrates". Current Sci., **26** (9): 285–86. Bangalore, 1957.
Vladimirov, V. I. "On the biological classification of fishes: through-running and semi-through-running ones". Zool. Zhurn., **36** (8): 1124. Moscow, 1957.
Voss, N. A. "Fishes of the family Gempylidae collected by the Bermuda Oceanographic Expeditions 1929, 1930, 1931 and 1934". Copeia, 1957 (4): 304–05. Baltimore, 1957.
Wald, G., Brown, P. K., & Brown, P. S. "Visual pigments and depths of habitat of marine fishes". Nature, **180** (4593): 969–71. London, 1957.
Wallin, O. "On the growth structure and developmental physiology of the scale of fishes". Rep. Inst. Freshw. Res. Drottningholm, **38**: 385–447. Lund, 1957.
Welander, A. D., Alverson, D. L., & Bergman, P. "Rare fishes from the eastern North Pacific Ocean". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 60–66. Olympia, 1957.
Widrig, T. M. "Measurement of population movement by observation of meristic or morphometric characters". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **208**: 29–34. Washington, 1957.
Williams, G. C. "Homing behaviour of California rocky shore fishes". Univ. California Publ. Zool., **59** (7): 249–84. Berkeley & Los Angeles, 1957.
Wright, P. G. "An electrical receptor in fishes". Nature, **181** (4601): 64. London, 1958.
Yamada, J. "On the mechanism of the appearance of the scale structure. V. The possible role of alkaline phosphatase in the formation of the teleost scale". Bull. Fac. Fish. Hokkaido Univ., **7** (3): 185–95. Hakodate, 1956.
Yamada, J. "On the mechanism of the appearance of the scale structure. VI. Some observations associating with the absorption of scale in the goldfish". Bull. Fac. Fish. Hokkaido Univ., **7** (3): 202–07. Hakodate, 1956.
Yamanaka, I. "Some remarks in estimating natural mortalities in population dynamics of fish resources". Ann. Rep. Japan Sea Reg. Fish. Res. Lab., **3**: 43–51. Niigata, 1957.
Yasuda, F., & Hiyama, Y. "Mechanism of utilization of plankton by some fishes". Rec. Oceanogr. Works Japan, **3** (1): 85–91. Tokyo, 1957.

7) Shellfish

7) a Molluscs

Abbey, A., Kohler, R., & Upham, S. D. "Effect of aureomycin chlortetracycline in the processing and storage of freshly shucked oysters". Food Technol., **11** (5): 265–71. Toledo, Ohio, 1957.
Anon. "Manual of recommended practice for sanitary control of the shellfish industry. Part II. Sanitation of the harvesting and processing of shellfish". US Dept. Health, Educat., & Welfare, PHS Publ., **33**. Washington, 1957.
Baird, R. H. "Some factors affecting growth and condition in mussels". Challenger Soc., **3** (9): 16. London, 1957.
Bang, F. B. "Reaction to injury in the oyster". Biol. Bull., **113** (2): 335. Lancaster, Pa., 1957.
Boury, M., & Borde, J. "Méthodes d'examin bactériologique de l'eau de mer et des coquillages; essais comparatifs". Sci. et Pêche, 1957 (51). Paris, 1957.
Butler, P. A. "Reproductive cycle in native and transplanted oysters". Proc. Nation. Shellf. Assoc., **46**: 75. Washington, 1956.
Cahnmann, H. J., & Kuratsune, M. "Determination of polycyclic aromatic hydrocarbons in oysters collected in polluted water". Analyt. Chem., **29**: 1312–17. Washington, 1957.
Chapman, C. R. "Feeding habits of the southern oyster drill, *Thais haemastoma*". Proc. Nation. Shellf. Assoc., **46**: 169–76. Washington, 1956.
Connell, J. H. "Spatial distribution of two species of clams *Mya arenaria* L. and *Petricola pholadiformis* Lamarck, in an intertidal area". 8th. Rep. Invest. Shellf. Massachusetts, Woods Hole Collect. Repr. 1955 (876). Woods Hole, Mass., 1955.
Davis, H. C., & Chanley, P. E. "Effects of some dissolved substances on bivalve larvae". Proc. Nation. Shellf. Assoc., **46**: 59–74. Washington, 1956.
Downes, K. M. "Manganese and zinc in the oyster *Crassostrea virginica*". Dissert. Abstr., **17**: 2711. Ann Arbor, Mich., 1957.

FINGERMAN, M. "'Brown-spotting' in the southern oyster". Commerc. Fish. Rev., **18**: 4–5. Washington, 1956.

FINGERMAN, M. "Body fluid of the oyster *Crassostrea virginica*". Publ. Inst. Mar. Sci., **4** (2): 284–92. Port Aransas, Texas, 1957.

FINGERMAN, M., & FAIRBANKS, L. D. "Osmotic behaviour and bleeding of the oyster *Crassostrea virginica*". Tulane Stud. Zool., **3** (9): 149–68. New Orleans, La., 1955.

FINGERMAN, M., & FAIRBANKS, L. D. "Bleeding and heat death in the southern oyster". Commerc. Fish. Rev., **18** (10): 4–5. Washington, 1956.

FOUND, H. R., & LOGIE, R. R. "Rehabilitation of disease-depleted oyster fisheries". Fish. Res. Board Canada, Atlantic Biol. Stat., Gen. Ser. Circ., **29**. St. Andrews, N. B., 1957.

GARDNER, E. A., & WATTS, B. M. "Effect of ionizing radiations on southern oysters". Food Technol., **11** (6): 329–31. Toledo, Ohio, 1957.

GUSTAFSON, A. H. "Growth studies in the quahog *Venus mercenaria*". Proc. Nation. Shellf. Assoc., **45**: 140–50. Washington, 1954.

KOBAYASHI, H. "Studies on the resistance of the pearl oyster, *Pinctada martensii* (Dunker), against changes of environment. IV. On the tolerance of the oyster considered from the relation between the ciliary movement and the heart beat". J. Shimonoseki College Fish., **6** (3): 337–46. Shimonoseki City, 1957.

KORRINGA, P. "Reproduction et cycles biologiques en relation avec les districts géographiques et la température. Water temperature and breeding throughout the geographical range of *Ostrea edulis*". Année Biol., **33** (1–2). Paris, 1957.

KORRINGA, P. "The supposed compulsory relation between oviparous oysters and waters of reduced salinity". Année Biol., **33**: 109–16. Paris, 1957.

LAFUSTE, J., *et al.* "La reproduction de l'huître portugaise (*Gryphaea angulata* Lmk.) dans les centres de captage de la côte atlantique". Rev. Trav. Inst. Pêches Marit., **21** (3): 401–14. Paris, 1957.

LOGIE, R. R. "Recent oyster mortalities and a method for restoring the fishery". Fish. Res. Board Canada, Atlantic Biol. Stat., Gen. Ser. Circ., **28**. St. Andrews, N. B., 1957.

LUND, E. J. "A quantitative study of clearance of a turbid medium and feeding by the oyster". Publ. Inst. Mar. Sci., **4** (2): 296–312. Port Aransas, Texas, 1957.

LUND, E. J. "Self-silting, survival of the oyster as a closed system and reducing tendencies of the environment of the oyster". Publ. Inst. Mar. Sci., **4** (2): 313–19. Port Aransas, Texas, 1957.

LUND, E. J. "Self-silting by the oyster and its significance for sedimentation geology". Publ. Inst. Mar. Sci., **4** (2): 320–27. Port Aransas, Texas, 1957.

LUND, E. J. "Effect of bleedwater, 'soluble fraction' and crude oil on the oyster". Publ. Inst. Mar. Sci., **4** (2): 328–41. Port Aransas, Texas, 1957.

LUND, E. J., & POWELL, E. "Note on the reflex inhibition of water propulsion by the oyster". Publ. Inst. Mar. Sci., **4** (2): 293–95. Port Aransas, Texas, 1957.

LUNZ, G. R. "Cultivation of oysters in ponds at Bears Bluff Laboratories". Proc. Nation. Shellf. Assoc., **46**: 83–87. Washington, 1955.

MACKIN, J. G. "*Dermocystidium marinum* and salinity". Proc. Nation. Shellf. Assoc., **46**: 116–28. Washington, 1956.

MARTEIL, L. "L'huître portugaise en Bretagne". Rev. Trav. Inst. Pêches Marit., **21** (3): 377–400. Paris, 1957.

MASON, J. "The age and growth of the scallop, *Pecten maximus* (L.), in Manx waters". J. Mar. Biol. Assoc., **36** (3): 473–92. Cambridge, 1957.

MENZEL, R. W. "Some additional differences between *Crassostrea virginica* and *Ostrea equestris* in the Gulf of Mexico area". Proc. Nation. Shellf. Assoc., **46**: 76–81. Washington, 1955.

MENZEL, R. W. "The effect of temperature on the ciliary action and other activities of oysters". Florida State Univ. Stud., **22**. USA, 1956.

MENZEL, R. W., & HOPKINS, S. H. "Crabs as predators of oysters in Louisiana". Proc. Nation. Shellf. Assoc., **46**: 177–84. Washington, 1956.

MILLS, D. H. "Herring gulls and common terns as possible predators of lobster larvae". J. Fish. Res. Board Canada, **14** (5): 729–30. Ottawa, 1957.

MUSSET, R. "À propos des huîtres portugaises". Norois, **2** (6): 235–36. Poitiers, 1955.

NELSON, T. C. "Some scientific aids to the oyster industry". American Sci., **45** (4): 301–32. New Haven, Conn., 1957.

SOMERVILLE, G. M., & DICKIE, L. M. "Offshore scallop explorations – 1957". Fish. Res. Board Canada, Atlantic Biol. Stat., Gen. Ser. Circ., **30**. St. Andrews, 1957.

VILELA, H. "Sobre exploraçao ostreicola". Bol. Pesca, 1954 (42). Lisboa, 1954.

Vilela, H. "As ostras no consumo e na economia nacional". Bol. Pesca, 1954 (43). Lisboa, 1954.
Yamamoto, G. "Tolerance of scallop spats to suspended silt, low oxygen tension, high and low salinities, and sudden temperature changes". Sci. Rep. Tohoku Univ., Ser. 4, **23**: 73–82. Tohoku, 1957.

7) b Crustaceans

Burger, J. W. "The general form of excretion in the lobster, *Homarus*". Biol. Bull., **113** (2): 207–23. Lancaster, Pa., 1957.
Dawson, C. E. "*Balanus* fouling of shrimp". Science, **126** (3282): 1068. Lancaster, Pa., 1957.
Dawson, C. E. "Studies on the marking of commercial shrimp with biological stains". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **231**. Washington, 1957.
George, R. W. "Continuous crayfishing tests: Pelsart Group, Houtman Abrolhos, Western Australia, 1953". Australian J. Mar. & Freshw. Res., **8** (4): 476–90. Melbourne, 1957.
Gordon, I. "A pseudo-hermaphrodite specimen of the lobster, *Homarus gammarus* (Linnaeus)". Ann. & Mag. Natur. Hist., **10** (115): 524–28. London, 1957.
Horsted, S. A., & Smidt, E. "The deep sea prawn (*Pandalus borealis* Kr.) in Greenland waters". Medd. Danmarks Fisk.- og Havunders., NS, **1** (11). København, 1956.
Lindner, M. J. "Survey of shrimp fisheries of Central and South America". US Dept. Inter., Fish & Wildl. Serv., Spec. Sci. Rep.-Fish., **235**. Washington, 1957.
Massuti, M. "La gamba y los crustaceos comestibles de la region Suratlantica". Industr. Pesqu., **31** (721–722): 44–45, 47, & 49–50. Vigo, 1957.
Rees, W. J. "The living scallop". The Scallop, Shell Transport & Trading Co. Ltd., London, 1957.
Simpson, A. C. "The determination of the parameters of lobster populations". Challenger Soc., **3** (9): 16. London, 1957.
Sutcliffe, W. H. "Observations on the growth rate of the immature Bermuda spiny lobster, *Panulirus argus*". Ecology, **38** (3): 526–29. Durham, N. C., 1957.
Tegelberg, H. C., & Smith, J. M. "Observations on the distribution and biology of the pink shrimp (*Pandalus jordani*) off the Washington coast". Washington Dept. Fish., Fish. Res. Pap., **2** (1): 25–34. Washington, 1957.
Velankar, N. K. & Govindan, T. K. "The free a-amino acid nitrogen content of the skeletal muscle of some marine fishes and invertebrates". Current Sci., **26** (9): 285–86. Bangalore, 1957.
Wald, G., & Burg, S. P. "The vitamin A of the lobster". J. Gen. Physiol., **40** (4): 609–25. Baltimore, 1957.
Wilder, D. G., & McLeese, D. W. "How temperature and crowding affect the holding of lobsters in artificial sea water". Fish. Res. Board Canada, Progr. Rep. Atlantic Coast Stat., **66**: 24–25. St. Andrews, N. B., 1957.

8) Mammals and Reptiles

Anon. "An analysis of recent catches of humpback whales from the stocks in groups IV and V". CSIRO, Rep. Div. Fish. & Oceanogr., **4**. Sydney, 1957.
Anon. "Beretning om selfangsten, håkjerringfisket og overvintringsekspedisjonene i 1956". Årsb. Vedk. Norges Fisk., 1956 (10). Bergen, 1957.
Anon. "Eighth report of the Commission. (Covering the eighth fiscal year 1st June, 1956 to 31st May, 1957)". Internat. Whaling Commiss., London, 1957.
Anon. "Reports of ringing and returns of grey seals: No. 1. September 1954 – August 1956". Proc. Zool. Soc. London, **128** (4): 594–95. London, 1957.
Ash, C. E. "Om størrelsen av den antarktiske finnhvalbestand sett i relasjon til størrelsen av fangsten". Norsk Hvalf.-Tid., **45** (8): 432–35. Sandefjord, 1956.
Backhouse, K. M., & Hewer, H. R. "A note on spring pupping in the grey seal (*Halichoerus grypus* Fab.)". Proc. Zool. Soc. London, **128** (4): 593. London, 1957.
Backhouse, K. M., & Hewer, H. R. "Behaviour of the grey seal (*Halichoerus grypus* Fab.) in the spring". Proc. Zool. Soc. London, **129** (3): 450. London, 1957.
Berdegue, J. "Ultimo censo de la ballena gris, *Rhachianectes glaucus* (Cope), en aguas de Baja California". Ciencia, **16** (4/6): 99–109. Mexico, 1957.

Boyd, J. M. "Aerial studies of a breeding colony of grey seals, *Halichoerus grypus* (Fab.), at Gasker, Outer Hebrides, in 1955 and 1956". Proc. Zool. Soc. London, **129** (3): 333–42. London, 1957.

Davies, J. L., & Guiler, E. R. "A note on the pygmy right whale, *Caperea marginata* Grey". Proc. Zool. Soc. London, **129** (4): 579–89. London, 1957.

Dawbin, W. H. "The migrations of humpback whales which pass the New Zealand coast". Trans. Roy. Soc. New Zealand, **84** (1): 147–96. Wellington, 1956.

Doropheev, S. V. "Resources of the Greenland seal and their exploitation". Rybn. Khoz., 1956 (12): 56–59. Moscow, 1956.

Figueiredo, J. M. "Biologia e pesca de cachalotes em S. Miguel, Acores". Bol. Pesca, **11** (55): 11–68. Lisboa, 1957.

Harrison, R. J. "Anatomical and functional adaptations in diving mammals". School Sci. Rev., **135**: 191–203. London, 1957.

Hewer, H. R., & Backhouse, K. M. "A red-headed grey seal (*Halichoerus grypus*)". Proc. Zool. Soc. London, **128** (4): 592. London, 1957.

Hurley, D. E., & Mohr, J. L. "On whale-lice (Amphipoda: Cyamidae) from the California gray whale, *Eschrichtius glaucus*". J. Parasitol., **43** (3): 352–57. Lancaster, Pa., 1957.

Ichihara, T. "An application of linear discriminant function to external measurements of fin whale". Sci. Rep. Whales Res. Inst., **12**: 127–89. Tokyo, 1957.

Ingham, S. E. "Elephant seals on the Antarctic continent". Nature, **180** (4596): 1215. London, 1957.

Kimura, S. "The twinning in southern fin whales". Sci. Rep. Whales Res. Inst., **12**: 103–25. Tokyo, 1957.

King, J. E. "On a pup of the crabeater seal *Lobodon carcinophagus*". Ann. & Mag. Natur. Hist., **10** (116): 619–24. London, 1957.

Klumov, S. K. "Coastal lying places of *Callorhinus ursinus* and living places of *Enhydra lutris* at the Kuril Islands, and a tentative determination of their respective number". Doklady Akad. Nauk SSSR, **117** (1): 153. Moscow, 1957.

Ladd, M., *et al.* "Filtration rate and water diuresis in the seal, *Phoca vitulina*". J. Cell.& Comp. Physiol., **38**: 157–64. Philadelphia, 1951.

Laws, R. M. "The elephant seal (*Mirounga leonina* Linn.). III. The physiology of reproduction". Sci. Rep. Falkland Islands Depend. Surv., **15**. London, 1956.

Laws, R. M., & Taylor, R. J. F. "A mass dying of crabeater seals, *Lobodon carcinophagus*". Proc. Zool. Soc. London, **129** (3): 315–24. London, 1957.

Montagna, W., & Harrison, R. J. "Specializations in the skin of the seal (*Phoca vitulina*)". American J. Anat., **100** (1): 81–114. Philadelphia, 1957.

Moore, J. C., & Wood, F. G. "Differences between the beaked whales *Mesoplodon mirus* and *M. gervaisi*". American Mus. Novit., **1831**: 1–25. New York, 1957.

Myers, B. J. "Nematode parasites of seals in the eastern Canadian Arctic". Canadian J. Zool., **35** (2): 291. Ottawa, 1957.

Nemoto, T. "Foods of baleen whales in the northern Pacific". Sci. Rep. Whales Res. Inst., **12**: 33–89. Tokyo, 1957.

Nishiwaki, M. "Age characteristics of ear plugs of whales". Sci. Rep. Whales Res. Inst., **12**: 23–32. Tokyo, 1957.

Nishiwaki, M. "Very small embryo of Cetacea". Sci. Rep. Whales Res. Inst., **12**: 191–92. Tokyo, 1957.

Nishiwaki, M. "One-eyed monster of fin whale". Sci. Rep. Whales Res. Inst., **12**: 193–95. Tokyo, 1957.

Nishiwaki, M., Hibiya, T., & Kimura, S. "On the sexual maturity of the sperm whale (*Physeter catodon*) found in the North Pacific". Sci. Rep. Whales Res. Inst., **11**: 39–46. Tokyo, 1956.

Ogawa, T., & Kamiya, T. "A case of the cachalot with protruded rudimentary hind limbs". Sci. Rep. Whales Res. Inst., **12**: 197–208. Tokyo, 1957.

Omura, H. "Osteological study of the little piked whale from the coast of Japan". Sci. Rep. Whales Res. Inst., **12**: 1–21. Tokyo, 1957.

Ottestad, P. "Om størrelsen av den antarktiske finnhvalbestand sett i relasjon til størrelsen av fangsten". Norsk Hvalf.-Tid., **45** (6): 298–308 & **45** (9): 480. Sandefjord, 1956.

Pew, P. "Occurrence of young dolphin, *Coryphaena hippurus*, in a Texas Bay". Copeia, 1957 (4): 300. Baltimore, 1957.

Quay, W. B. "Pancreatic weight and histology in the white whale". J. Mammal., **38** (2): 185–92. Baltimore, 1957.

TAVOLGA, M. C., & ESSAPIAN, F. S. "The behavior of the bottle-nosed dolphin (*Tursiops truncatus*): mating, pregnancy, parturition and mother-infant behavior". Zoologica, **42** (2): 11–31. New York, 1957.

TAYLOR, F. H. C. "Distribution and food habits of the fur seals of the North Pacific Ocean: report of cooperative investigations by the governments of Canada, Japan and the United States of America". US Fish. & Wildl. Serv., Washington, 1955.

UDA, M., & DAIROKUNO, A. "A study of the relation between the whaling grounds and hydrographic conditions. (II). A study of the relation between the whaling grounds off Kinkazan and the boundary of water masses". Sci. Rep. Whales Res. Inst., **12**: 209–24. Tokyo, 1957.

WORTHINGTON, L. V., & SCHEVILL, W. E. "Underwater sounds heard from sperm whales". Nature, **180** (4580): 291. London, 1957.

9) Miscellaneous

9) a Mathematical and Statistical Methods

DOI, T. "Some considerations of the personal error and precision in observing biological property of fish in relation with the communication theory". Bull. Tokai Reg. Fish. Res. Lab., **15**: 1–13. Tokyo, 1957.

HENNEMUTH, R. C. "An analysis of methods of sampling to determine the size composition of commercial landings of yellowfish tuna (*Neothunnus macropterus*) and skipjack (*Katsuwonus pelamis*)". Bull. Inter-American Trop. Tuna Commiss., **2** (5). La Jolla, Cal., 1957.

TANAKA, S. "Relation between Baranov's mathematical model and sigmoid curve". Bull. Japanese Soc. Sci. Fish., **23** (1): 12–18. Tokyo, 1957.

9) b General

ANON. "World fisheries: general trends and outlook with examples from selected countries". FAO, The State of Food and Agriculture 1956: 100–27. Rome, 1956.

ANON. "Oceanographic papers in Japan. (Annotated bibliography). (1873–1938)". Japanese Nation. Commiss. UNESCO, Tokyo, 1957.

ANON. "Trawler-icing research". Rep. British Shipbuilding Res. Assoc., **221**. London, 1957.

BROWN, F. A., WEBB, H. M., & MACEY, E. J. "Lag-lead correlations of barometric pressure and biological activity". Biol. Bull., **113** (1): 112–19. Lancaster, Pa., 1957.

DROOP, M. R. "Vitamin B_{12} in marine ecology". Nature, **180** (4594): 1041. London, 1957.

GRAHAM, M. "English fisheries research". Fish. Year Book & Direct. 1957: 59–63. London, 1957.

KNIGHT-JONES, E. W. "Marine biology in Wales. Inaugural lecture of the Professor of Zoology delivered at the College on December 4, 1956". Univ. College, Swansea, 1957.